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3, Amersham Road, HIGH WYCOMBE, Bucks.
Telegraphic Address: "Zacatecas, High Wycombe."
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Telephone: Colmore 4274-4275 Telegrams: CIRA
The B.C.I.R.A. Scottish Laboratories are:—
Foundry Technical Institute, Meek's Road, Falkirk
Telephone: 332

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Mental Improvisation

After a careful study of the discussion which followed the presentation of Mr. Dunleavy's Paper at Manchester on "The Foundryman and the Metallurgist," we feel that the situation has been left in a nebulous condition, and our object is to straighten out matters. As Mr. Norman Cook pointed out, much of the help given by the metallurgist was not of a metallurgical nature, but would be embraced by the word "technological." There was a general agreement that "small" foundries could not afford the services of the metallurgist. It would be better to relate this factor to the *value* of the output, for some of the highly-specialised foundries are not large viewed from the angle of the labour force. High Duty Alloys—a firm of very considerable magnitude to-day—had a high percentage of metallurgists when Mr. Devereux commenced business with a handful of men. The relative *value* of the output was initially high.

The next point of general agreement was that no matter what the size of the foundry, metallurgical help was an asset. Obviously metallurgical assistance costs money—so does clerical help and labour-saving machinery. In the case of the latter, someone possessing more or less erudition does some arithmetic, and reaches the conclusion that its acquisition would be advantageous. The better-placed individuals can state that the savings (with the various provisos) will be of the order of so many pounds a year. Others have to content themselves with the surmise that it looks a good gamble. This latter phrase can be more often associated with the smaller concerns. An expert would certainly give a fairly near approximation. So, too, with metallurgical services, and the small concerns, in order to preserve their continuity of existence, should include in their sales price a percentage for technical services. The money so earmarked should be laid out to the best advantage, for initially the appointment of a full-time technician will be ruled out. However, metallurgical services of a co-operative character are well within the reach of the most modest concerns. Money always seems to be forthcoming for legal services in the case of some disputed waster. The lawyers will soon discover metallurgical experts to advise the judge in his decisions. These same experts will accord a much lower fee to clients seeking their services before trouble has arisen!

The third phase of the discussion was that, unlike a piece of labour-saving machinery, the technologist was an unknown quantity and could not be guaranteed to deliver the goods. This may be an advantage, as he can be more easily dispensed with, under normal conditions, than can useless machinery. The scientist who fails to take his place in the team should be transferred. Foundry owners should beware of the type of man who insists on the initial establishment of a well-equipped laboratory. The tooling of the laboratory will come naturally consequent upon the exigencies of the services as they may arise from time to time. For routine analysis to take up all the time of the metallurgist is exactly like a skilled loam moulder making up hundreds of runner bushes.

The last phase to be discussed was what that nebulous individual designated the "foundryman" should contain within the ambit of experience. There was the tacit assumption that he should be well versed in the art of moulding, yet should such a foundryman be appointed to manage a foundry manufacturing spun pipes by the de Lavaud process, such knowledge would not carry him far! Surely the essential attributes are a profound knowledge of foundry practice in as many branches as possible, without being a Jack-of-all-trades; leadership; and the principles of manufacturing, embracing such subjects as the laying out of the work, routing, and co-ordinating the efforts of his staff. If an executive be profoundly ignorant of some phase of activity of which his department really stands in need, let him openly acknowledge the fact, and acquire such a service through the most appropriate channel. The foundry industry has suffered too long from improvised, home-made machinery, and this makes it essential that, under modern conditions, the foundryman should eschew improvised services, be they metallurgical, engineering, or relative to costing and estimating. Unless he be confident that he is master of the subject impacting on his department, the obvious remedy is not to improvise but to insist that skilled help be given.

Use of Magnetic Devices in Foundries

MR. W. E. BOX, a member of the Birmingham Branch of the Institute of British Foundrymen, recently gave a lantern lecture to the Scottish Branch, meeting in Glasgow. The subject of the lecture was "The Application of Lifting Magnets, Magnetic Separators, Clutches, Chucks and Specials."

The first group illustrated and detailed special magnets, lifting gear, spring drums and the like. Lifting magnets were generally applied, the lecturer said, where it was desirable to speed up production and reduce handling charges in industrial establishments where ferrous materials were handled. Sketches were made to indicate the three general types standardised. The application of lifting magnets included a study of rectangular and bi-polar types of magnets in handling long plates, tubes, rolled sections, stalloy sheets, etc.

The lecturer, after again giving diagrammatic sketches of magnetic separators, indicated the internal constructional features, and mentioned that the purpose of applying magnetic separators generally could be grouped under three headings: (*a*) Purifying, concentrating, and refining materials such as ores, liquids, chemicals, foodstuffs, resins, etc.; (*b*) preventing dust explosions, fire, and damage to crushers, grinders, pulverisers, disintegrators, pumps, cutter knives, rag-tearing machines, worm feeds, elevators, calender rolls, reduction process mechanisms and handling plant; and (*c*) reclaiming and salvage generally, such as tins from house refuse, ferrous articles and materials from mixed swarf, joinery waste, foundry sand, floor sweepings, and dumps.

The main scope of the lecture was confined to magnetic separation as used in ferrous and non-ferrous foundries, and, among the types of separators available for these industries, the speaker described the magnetic pulleys, overband separators, for use in ferrous foundries, for extracting gits, brads, spillings from knock-out foundry sand. Drums, chutes and other types of magnetic equipment were described as used in non-ferrous foundries for refining purposes and where it was desirable for treating mixed scrap and mixed swarf. Magnetic clutches were then described, and examples of applications were pointed out where they could be used for general transmission purposes, offering a simple and foolproof method of positively controlling the engagement or disengagement of power. Examples were generally explained where clutches were used for starting synchronous motors under full load conditions, and other examples for use in conjunction with operating screw-down gear in rolling mills, etc.

It was pointed out that in some cases clutches could be combined with electro-magnetic brakes in connection with cranes, where it was necessary to hold a load in the event of current failure. Magnetic chucks were then described as used in machine shops particularly for holding work during difficult grinding, boring, drilling, shaping and other operations.

Finally, control gear and accessories were dealt with, and many of the members present expressed surprise at the wealth of standardised equipments of this nature available to the industry for the saving of labour and material, and for salvage, which is so essential at the present time.

After an interesting and prolonged discussion, a vote of thanks was accorded to the lecturer, who suitably replied, saying how pleased he was that so much interest had been shown at question time by the members.

Book Review

Works Boiler Plant. By F. J. Matthews, B.Sc. (Hons.). Published by Hutchinson's Scientific & Technical Publications, Paternoster House, Paternoster Row, London, E.C.4. Price 10s. 6d. net.

It would seem to the reviewer that a more suitable title would have been "Factors Governing the Economic Production of Steam." Consideration has not been given to a study of the various types of steam raisers, but apart from this every factor relative to the economic production of steam has been carefully and exhaustively dealt with.

Chapters are devoted to "Combustion," "Fuel Factors," "Heat Recovery," "Feed Water Treatment," "Boiler Fittings and Auxiliaries," "Operation and Maintenance," "Boiler Testing," etc. For the engineering student the book will prove a valuable guide to the economic production of power, having in mind that factory or workshop economy must start at the foundation—the boiler house.

Primarily, no doubt, written for the student, the work possesses a much wider field of interest. The chapters devoted to "Heat Economies," "Tracing Troubles and their Correction," "Operation and Maintenance Topics" and "Boiler Testing," together with a number of the tables included, may well prove of useful and material assistance to the charge engineer. The data are reassembled in an exceedingly informative manner, expressed in the simplest possible language and profusely illustrated.

P. FOX-ALLIN.

EDITORIAL INDEX TO VOL. 63

The editorial index to Volume 63 of the Journal (July to December, 1940) is now ready for printing. Readers who wish to receive a copy are asked to make early application to the Publisher, 3, Amersham Road, High Wycombe, Bucks.

Diaries and Calendars

We acknowledge with sincere thanks the receipt of the following Christmas gifts, and heartily reciprocate the good wishes which accompanied them:—

Hargraves Brothers (Foundry Supply Department), Wheathill Street Works, Salford—A monthly tear-off wall calendar.

H. Hendra & Sons, Townmead Iron Foundry, Beddington Lane, Croydon, Surrey—A neat desk calendar carried in a green and gold frame.

John G. Stein, Limited, Bonnybridge, Scotland—A four day to the page pocket diary. Very useful technical data germane to refractories, a number of interesting maps and much useful information are included.

High Duty Alloys, Limited, Slough—A three day to the page pocket diary carrying a mass of technical data about light alloys, yet so presented as to occupy a minimum of space.

Stewarts and Lloyds, Limited, of London and elsewhere—A monthly desk calendar in a white frame decorated by the Union Jack.

I.C.I. Metals, Limited, Kynoch Works, Wilton, Birmingham, 6—A pocket diary carrying four days to the page, prefaced by a 40-page insert giving useful technical data.

Thomas & Clement, Limited, Llanelly—A two-day to the page pocket diary, an allowance which makes the real keeping of a diary an easy matter.

Random Shots

It was a strange coincidence that made two Past-Presidents of the Institute of British Foundrymen choose Christmas cards of the same design—or was it their wives' choice? The delightful picture on the front is tantalisingly familiar, and its identity has worried "Marksman" all through the Christmas period! It is a rustic scene of a bend in a country lane, flanked on both corners with Tudor cottages. In front of one group of cottages is an old oak tree. It looks very much like that notable spot, the very Middle of England, to which cyclists all over the country make, or used to make before the war, an annual pilgrimage. Or can it be a reproduction of one of those charming photographs of the English countryside which "The Times" publishes now and again as a refreshing contrast to pictures of war destruction?

* * *

The best joke of this year's pantomimes was surely the one unconsciously "put over" at the local theatre at which "Marksman" indulged in a couple of hours' relaxation this Christmas. The curtain has not yet been raised, but as the conductor of the orchestra takes his place he is greeted by loud applause from the stalls, where evidently he has some regular followers.

"Thanks," says the conductor, "but wait till you see the pantomime. You'll stop clapping then!"

* * *

There seems, by the way, to be a real scarcity of popular pantomime songs this year. Even the soldiers revert to the old songs of the last war when they want a really good sing-song with plenty of pep in it. Maybe everyone is too busy to think of new songs, or perhaps it is because conditions change so rapidly that a song is out of date before it has had time to "catch on." In the last war "Take Me Back to Dear Old Blighty" rang true to popular sentiment over the whole four years. In this war, on the other hand, "We'll Hang Out Our Washing on the Seigfried Line" soon became as dead as mutton (though who knows when it might be revived with renewed vigour and a new significance?), whilst "Run, Rabbit, Run" only serves to remind one that it is a far cry from present-day conditions to the almost halcyon days when the enemy's "bag" was one rabbit, one sheep and a disused cowshed. The catch song which "Marksman" heard at his local pantomime was out of date even before it was let loose on the public market. It began with "N'apples, N'anas and N'oranges," and went on to induce the youngsters to clamour for them (instead of sweeties) in order to grow big, healthy and strong. The panto was produced on December 26; "N'anas" went out of fashion on December 21.

* * *

Journalist's Idea of a Conveyor!

Robin Duff, of the B.B.C.: "And they were being sent round the factory by one of those contraptions which flings things around."

* * *

Progress.

Charwoman: "And how old is your little girl?"

Mistress: "Ten years next July."

Charwoman: "Ah, well, you might as well say that she's reared!"

What a neat reflection on the good old days in which all children over ten years were divided into two classes: those who are dead, and those who have survived!

* * *

Notice on a Communal Shelter.

"Users of this shelter are reminded that this is not a store room, but a snore room."

"MARKSMAN."

Gravity Die-Castings in a High-Strength Aluminium Alloy

The unusually rapid rate of development which has, during the past decade, been an outstanding feature of light-alloy metallurgy—with regard both to products and practice—has called for intensive researches in numerous directions in order that the fullest advantage could be taken of what has virtually proved to be an entirely new range of constructional materials. In no single direction has the progress made been more marked than in the case of foundry technique.

Readers will no doubt be familiar with the prejudice which for long existed against the use of cast alloys for parts likely to be subjected to appreciable stresses in service. The pioneer work of Hadfield, in demonstrating the great reliability of high-quality steel castings, will long be remembered in this connection. The improved range of foundry materials now available, the realisation of the importance of high purity in alloy constituents, and the evolution of efficient methods for avoiding porosity and blowholes in castings, have all contributed their quota to the considerably increased reliance which engineers are now invariably disposed to place on cast metal products.

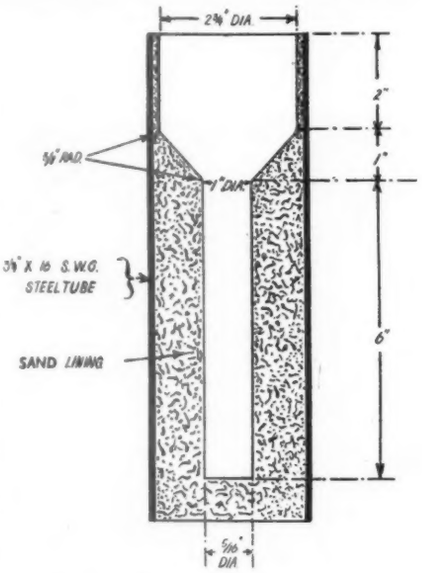


FIG. 1.—MOULD FOR TEST SAMPLES.

In one particular respect the development of aluminium-alloy castings suffered from serious initial disadvantages—the poor casting properties of aluminium metal itself, and its low strength in the cast form—such disadvantages restricting the use of cast aluminium to cases in which the outstanding chemical and physical properties of the metal were essential in the final product.

The discovery of casting alloys of aluminium which combined to a great degree the physical and chemical properties of the metal with considerably higher strength and excellent casting qualities marked a major advance in the industrial utility of aluminium alloys, an advance tempered only by the fact that for some considerable time no elongation figure could be guaranteed in the case of the alloys of higher strengths.

High and Low Strength Materials

Generally speaking, the strength criterion usually applied to light alloys is the 0.1 per cent. proof stress, a figure of 11 tons per sq. in. being usually accepted as marking the line of division between the high-strength and low-strength materials. Alloys which meet this requirement with regard to strength have been used for some years, amongst them being the well-known "Y" alloy with a proof stress of approximately 14 tons per sq. in. A considerable forward step was made in sand-casting alloys, however, with the evolution of alloy N.A. 226 which, in fulfilling the conditions laid down in D.T.D. specification 361, provides a proof stress in excess of 20 tons per sq. in., allied to a guaranteed elongation figure of over 1 per cent.

Mechanical Properties

This alloy, which is of the copper-containing type as shown in Table I, is actually covered by two further Air Ministry specifications in addition to D.T.D. 361; namely, D.T.D. 298 and D.T.D. 304. In these two specifications the heat-treatment practice is modified so that, although the strength figures are lower, the elongation is much increased. Strength figures reached by manufacturers of the alloy to the various specifications are also included in Table I.

TABLE I.—*Chemical Composition and Mechanical Properties achieved by Manufacturers of N.A. 226 to D.T.D. 361, 304 and 298.*

Alloy.	Chemical composition. Per cent. Cu.	Si.	Fe.	Ti.	Impurities (Mg, Mn and Zn).	0.1 per cent. proof stress. Tons per sq. in.	Ultimate tensile stress. Tons per sq. in.	Elongation per cent. on 2 in.	Heat-treatment.
N.A. 226 to D.T.D. 361 Sand-cast	4.0 to 5.0	0.9 max.	0.7 max.	0.25 max.	0.2 max.	21.0	23.0	1.5	Heat at 250 to 545 deg. C. for not less than 16 hrs. Quench in water or oil. Reheat at 160 to 170 deg. C. for 8 to 16 hrs. Cool in air.
N.A. 226 to D.T.D. 361 Chill-cast						24.0	27.0	5	
N.A. 226 to D.T.D. 304 Sand-cast	As above.					15.0	19.0	5	Heat at 525 to 545 deg. C. for 12 to 16 hrs. Quench in water. Reheat at 120 to 170 deg. C. for 12 to 24 hrs. Cool in air.
N.A. 226 to D.T.D. 304 Chill-cast						18.0	25.0	10	
N.A. 226 to D.T.D. 298 Sand-cast	As above.					12.0	15.5	10	Heat at 525 to 545 deg. C. for not less than 12 hrs. and quench in water. Follow optionally by reheating to 130 deg. C. for 1 to 2 hrs. and air cooling.
N.A. 226 to D.T.D. 298 Chill-cast						15.0	19.0	15	

The methods whereby the required high quality of the alloy is achieved lie chiefly in the directions indicated, that is, by the employment of high-purity constituents and exercising strict control over foundry technique. Thus, in the relevant specifications, it is required that the aluminium used shall conform to the requirements laid down in B.S. Specification L.31, whilst the copper used must be of a standard of purity equal to that of electrolytic copper.

Test-Pieces

Special requirements are also laid down with regard to the provision and preparation of test samples. At least one test sample must be cast to represent each large casting, whilst when castings are made from more than one charge, and the charges are not mixed prior to casting, a test sample must be cast from each charge. If small castings be made by taking metal from a larger charge, a test sample must be cast for every 100 lbs. of metal poured.

Metal for the samples must be taken directly from the same crucible or ladle from which the castings are to be poured, the only treatment to which such metal may be subjected being the cooling down to the appropriate pouring temperature. The test samples are cast in dry-sand moulds of the type shown in Fig. 1, the mould (which, prior to casting, should be at a temperature between 10 and 40 deg. C.) being rammed in one piece. During pouring, the test mould should be inclined at an angle of 30 deg. to the vertical, pouring, of course, taking place from the top.

The success which attended the use of this casting alloy for parts subjected to relatively high stresses in service naturally led to investigations into the possibility of producing formed parts by die-casting, and, as a result of intensive experimental work, it has been found that the material is suitable for certain types of gravity die-castings. The advantages, economic and otherwise, which result from the use of the gravity die-casting process, are well known to all foundrymen. In the case of the material under discussion, however, the advantages gained are, as will be realised from the following discussion, considerably enhanced by the intrinsic properties of the material.

Aircraft Die-Castings

The first and most obvious field of development is in aircraft, where the importance of employing the material which most favourably meets the demand for strength and lightness transcends any consideration of cost. Yet it is in this field particularly that high-strength aluminium alloy die-castings may be used to effect economy of cost as well as of weight, whilst in certain special cases they may well be employed to achieve greater convenience and cheapness of assembly in spite of a slight increase in weight.

Parts which are normally built up from wrought metal in the form of forgings involving costly dies, or built up from sheet and extruded sections with considerable expense in machining and welding, may be gravity die-cast in the high-strength aluminium alloy, examples of such applications being tube sockets, junction plates, brackets and levers of all types. In Fig. 2 is shown a group of forgings of types which render them suitable for gravity die-casting.

The principal requirements in some cases may not be high tensile strength so much as the possession of the requisite stiffness combined with ease of assembly. Where components are subjected to shock, and particularly where momentary excess loadings are likely to be encountered, the choice will then fall upon an alloy with high elongation, such as N.A. 226 to specifications D.T.D. 298 or 304.

In the event of the local stresses experienced exceeding the designed strength of the component as a whole, the high elongation material will give slightly before fracture takes place. This slight distortion is in many cases sufficient to eliminate the local stresses which cause it, and thus the structure is restored to equilibrium. Since cast aluminium alloys with high elongation have become available only recently, it is in parts subject to sudden and unsteady loadings that castings are provided with a new field of application.

clusively employed, whilst, with but slight modification to design, the material may be substituted for malleable cast iron, bronze or gunmetal.

It must, however, be pointed out that there are several limitations to the use of the alloy as a gravity die-casting material. The remainder of this article will therefore be devoted to discussion of foundry characteristics, together with a review of some components produced during the development work carried out to determine the suitability of the material for gravity die-casting.

Foundry Properties

First, the material does not flow as readily as the silicon-bearing alloys or some of the more complex alloys. In casting any alloy it is desirable to avoid wherever possible feeding a thick section through a thin one, and this point is of particular importance with N.A. 226. It is imperative that adequate feed should be provided to thick sections in view of the lower fluidity of the alloy, since the skin formed in the thin sections due to the chilling effect is likely to obstruct the flow of the metal, and form a "cold shut." Sections less than about $\frac{3}{16}$ in. thick are in general to be avoided, though examples of thinner sections will be seen embodied in parts that are considered practicable as die-castings in the material.

Other points requiring consideration are shrinkage on solidification and hot-shortness. The former feature still further increases the desirability of heavy feed in order that shrinkage cavities and "draws" may be avoided. The effect of the two properties in combination is that in a thin section adjacent to a thick section, and more especially in a thin section between two thick sections, the metal may be drawn on solidification due to shrinkage, and this may result in cracking owing to hot-shortness. In some cases this trouble may be avoided by the application of suitable foundry technique. Another point to be watched is that adequate radii should be provided, both in order that the metal may flow into the corners, and also to facilitate extraction from the die.

These considerations all lead to complexity of die design, so that in many cases parts which may be fairly easily cast in an alloy such as N.A. 244 (which flows freely, has moderate shrinkage on solidification, and is not hot-short) are not practicable for production in N.A. 226.

In Fig. 3 is illustrated a gravity die-cast box section, without bottom, in which the walls are of more or less uniform section, even in the corner where the large boss is cored out, the main core in this case being of cast iron. Little

(*Continued on page 6.*)

FIG. 2.—FORGINGS OF TYPES SUITABLE FOR SUBSTITUTION BY GRAVITY DIE-CASTINGS IN N.A. 226 ALUMINIUM ALLOY.

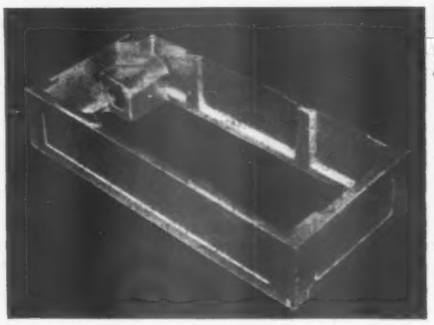


FIG. 3.—DIE-CAST BOX SECTION WHICH CAUSES LITTLE DIFFICULTY IN PRODUCTION.

FIG. 4.—HOUSING WHICH REQUIRED A SAND CORE FOR SUCCESSFUL DIE-CASTING.

Where maximum rigidity under normal loading is not required, the ruling consideration will be the adoption of the thinnest possible section, this, of course, depending upon the ultimate tensile strength of the material. In such cases the use of N.A. 226 to D.T.D. 361 or 304 provides, in addition to the necessary strength, a reliable elongation figure which will prevent failures due to unexpected local stressing beyond the elastic limit.

Other Applications

As will be well appreciated, it is not only in aircraft that the alloy provides new applications for castings. Components of transport equipment, in which high power:weight ratio is desirable, and parts of high-speed or variable-speed machinery, in which inertia forces must be minimised and the components must possess the ability to withstand shock loads, are examples of applications suitable for strong, light alloys with high elongation.

Thus, in many cases the alloy to the previously-mentioned specifications is now used for parts for which steel had formerly been ex-

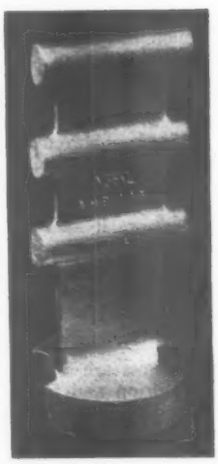


FIG. 5.—SECTION WHICH INVOLVED DIFFICULTIES IN FEEDING AS A DIE-CASTING.

Ladle Additions of Graphite to Grey Cast Iron*

By A. H. DIERKER

The addition of any type of material to the molten metal, whether in the runner, in the forehearth, or in the ladle, will, for the purpose of this discussion, all be classified as ladle additions. In considering such additions, it would seem advisable to think of them as corrective agents rather than as part of the cupola operation. There would appear to be little advantage in going to the trouble and expense of making a ladle addition merely to secure certain properties in the iron when the same properties can be obtained by some small adjustment in the cupola practice.

Nevertheless, there are times when convenience, necessity, or cost would indicate the advisability of some type of ladle addition, and it is for such occasions that the following data on graphite, as one agent widely used for the purpose, are presented.

No attempt will be made to discuss the production and properties of the graphite used for this purpose, nor will the commercial use of the material in foundries be discussed. This Paper will be confined to the results of laboratory experiments on cupola and electric-furnace irons.

Graphite, commercially available, is of two general types: artificial and natural, and can be obtained in a number of different mesh sizes. Both types in different mesh sizes were used in these investigations.

Graphite a Chill Reducer

Graphite, as a ladle addition, is used primarily as a chill reducer and experience to date would indicate that it is most effective in this respect. Where graphite is used as an addition to reduce chill, it is important to know what effect, if any, it might have on the mechanical properties. This investigation was directed largely in that direction.

Three melts were run in a small cupola of the Industrial Engineering Laboratories, Ohio State University. This cupola is lined to 22 in. inside diameter. The same metallic charge was used for each run. Variations in total carbon between the different runs were secured by variations in cupola operation. The charge was as follows:—

Material	Per cent.	Weight, lbs.
Steel scrap	40	120
Cast scrap	38	114
Pig-iron	22	66

The analysis of these materials is given in Table I. Cupola operations for the three runs are listed in Table II.

TABLE I.—*Percentage Analysis of Raw Materials in Cupola Charge.*

	C.	Si.	Mn.	S.	P.
Steel scrap	0.84	0.18	0.54	0.03	0.02
Cast-iron scrap	3.61	1.91	0.45	0.08	0.55
Pig-iron (silvery)	2.32	7.08	1.06	0.02	0.14

Melting Procedure

The procedure followed in each run was as follows: The blast was put on and melting proceeded until a small amount of metal had accumulated in the crucible of the cupola. Approximately 100 lbs. of metal was then tapped out and discarded. Melting proceeded until the slag began to run into the tuyeres. One thousand lbs. of metal was then tapped into an insulated and covered ladle which had been well preheated. Hand shanks, filled from the large ladle, were used in pouring the test castings.

Graphite additions were made as the hand shanks were being filled. Each shank held approximately 40 lbs. of metal, and 20 grms. of graphite was added in each case; hence, the amount added was approximately 0.11 per cent. The graphite added was of two different types, artificial and natural. The natural graphite added was of two grades, a rather coarse material known as No. 8 Mexican, and widely used for this purpose, and a fine powdery material. The artificial graphite was of three grain sizes, through 8 and on 14 mesh, through 14 and on 35 mesh, and through 35 mesh.

Thirteen ladles of iron were poured from each run, two with each type of graphite addition and three with no additions. The three standard A.S.T.M. transverse bars were poured as test specimens. These bars were poured horizontally. Tensile specimens were machined from broken halves of the transverse bars.

The chill test was a type widely used in foundries. Details of the specimen and method of casting are shown in Fig. 1. With iron of the general composition used in these experiments, this type of test gives a fairly sharp line of demarcation between the chilled and unchilled portion of the iron. It is not difficult to measure the depth of chill with reasonable accuracy.

TABLE II.—*Data on Cupola Operation for Each of Three Runs.*

	Melt No. 8	Melt No. 9	Melt No. 10
Type of coke	By-product	70 per cent. by-product, 30 per cent. pitch	By-product.
Height of coke bed above tuyeres	46 in.	46 in.	54 in.
Coke between charges	35 lbs.	35 lbs.	35 lbs.
Type of flux	1-in. limestone	1-in. limestone	1-in. limestone
Amount of flux on each charge	8 lbs.	8 lbs.	8 lbs.
Size of metallic charge	300 lbs.	300 lbs.	300 lbs.
Number of charges	4	4	4
Blast volume	900 c.f.m.	900 c.f.m.	1,000 c.f.m.

TABLE III.—*Average Mechanical Properties of Bars Tested.*

	Ladle additions.					
	Melt No. 8.		Melt No. 9.		Melt No. 10.	
	None.	Graphite.	None.	Graphite.	None.	Graphite.
Chemical analysis—						
T.C	3.05	3.14	3.40	3.43	3.10	3.17
Si	1.91	—	2.19	—	2.37	—
Mn	0.37	—	0.44	—	0.45	—
S	0.116	—	0.104	—	0.120	—
P	0.231	—	0.234	—	0.254	—
Chill depth, in.	0.219	0.136	0.138	0.086	0.126	0.064
0.875-in. dia. bar—						
Transverse strength, lbs.	—	1,893	1,500	1,532	1,975	1,906
Deflection, in.	—	0.189	0.185	0.191	0.218	0.211
Tensile strength, tons per sq. in.	—	21.6	15.4	15.0	19.4	19.8
Brinell hardness number	—	237	201	194	217	222
1.2-in. dia. bar—						
Transverse strength, lbs.	2,965	3,132	2,246	2,191	3,002	2,874
Deflection, in.	0.325	0.366	0.295	0.322	0.370	0.355
Tensile strength, tons per sq. in.	19.4	19.1	13.5	12.7	18.1	17.9
Brinell hardness number	221	218	192	182	217	213
2.0-in. dia. bar—						
Transverse strength, lbs.	10,700	10,440	7,160	6,780	9,405	9,360
Deflection, in.	0.419	0.422	0.372	0.375	0.413	0.438
Tensile strength, tons per sq. in.	16.7	17.5	10.0	9.9	14.5	14.4
Brinell hardness number	197	197	134	135	174	170

TABLE IV.—*Test Results of Electric-Furnace Iron.*

No.	Chemical analysis. Per cent.						Chill depth. In.	Transverse 1.2-in.				Graphite added to ladle.
	T.C.	Si.	Mn.	P.	S.	Cr.		Break. Lbs.	Def. In.	Brinell hardness number.	Tensile strength. Tons per sq. in.	
272–6	3.24	1.94	0.61	0.30	0.06	0.09	0.28	—	—	*212	*18.6	None.
272–3	—	—	—	—	—	—	0.09	—	—	*197	*16.7	0.15 per cent. N.G.† 28–48 mesh.
276–3	2.99	2.22	0.43	0.17	0.05	0.65	0.50	2,860	0.220	235		
276–1	3.09	—	—	—	—	—	0.32	3,270	0.285	241	21.5	None.
											21.2	0.11 per cent. N.G. 28–48 mesh.
280–4	3.10	2.44	0.47	0.14	0.11	0.63	0.38	3,410	0.230	235		
280–3	3.16	—	—	—	—	—	0.25	3,540	0.341	235	23.3	None.
											23.4	0.15 per cent. N.G. 14–28 mesh.

* From bar 1.25 in. by 1.25 in. by 18 in. † N.G. = natural graphite.

* Paper presented before the 44th annual American Foundrymen's Association convention at Chicago, Ill. The author is Research Engineer at the Engineering Experiment Station, Ohio State University.

Tapping and pouring were done as quickly as possible to secure a minimum temperature drop in the metal during the pouring operation. For this reason, it was rather difficult to get accurate temperature readings with the optical pyrometer. However, the readings taken indicated a temperature drop of less than 55 deg. C. between the first and last casting period.

A table (not reproduced) gave in detail the results of the mechanical and chill tests and chemical analysis. In Table III these results have been summarised. The analysis for total carbon would indicate that the recovery is good and that better recovery is secured at higher metal temperatures. The tests are probably too few to draw any other or more definite conclusions in this respect.

Graphite Type and Size

Although the author was interested in determining the best type and size of graphite to use for this purpose, he feels that the tests to date have not been carried far enough for any definite conclusions along this line. He does feel justified in saying that the very fine mesh sizes, as well as the very coarse particles, are unsatisfactory as ladle additions. In both cases recovery is poor and the results undependable. It also has been observed that the very fine mesh size has a tendency to cause porosity in the metal. It is indicated that the graphite should not be coarser than 8 mesh nor finer than 48 mesh. A detailed study gives a rather confusing picture of the effect of the graphite additions on mechanical properties. However, the averages, given in Table III, would indicate that the mechanical properties are not affected materially one way or the other. However, a detailed investigation does show the danger of drawing conclusions from a few isolated tests, because, by choosing the appropriate data, one could prove that graphite ladle additions have a marked effect in improving the mechanical properties. At the same time, by choosing other figures, one could prove the exact opposite.

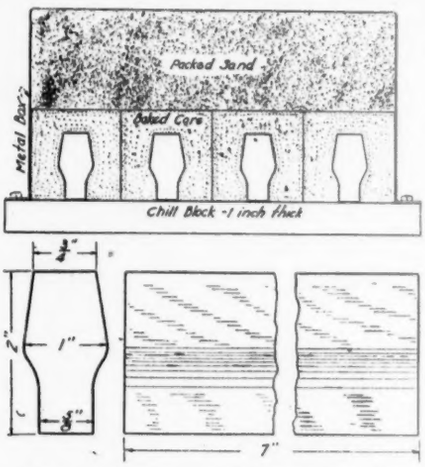


FIG. 1.—METHOD OF CASTING CHILL-TEST SPECIMEN (TOP) AND DETAILS OF SPECIMEN.

One of the most significant facts brought out by this particular series of tests is the marked change in the properties of the iron that can be secured by a change in cupola operation. All of these operations were with identical metallic charges, and were of a type paralleling commercial practices, yet the tensile strength of the 1.2-in. dia. bars shows a variation of more than 30 per cent. with other properties varying accordingly.

Table IV gives the results of tests of electric-furnace iron to which ladle additions of

(*Continued in next column.*)

(*Continued from previous column.*)

graphite were made. It is interesting to note that, although the tensile strength is about the same, the graphite addition has increased the transverse strength as well as the total deflection. It is thought that the graphite additions would have more effect on harder irons of this type than on the type of iron that has been discussed.

Microstructure

In studying the microstructure of the different test-bars made in this investigation, a noticeable and consistent difference was found in only one respect. The specimens made from iron to which graphite additions had been made showed a finer grain size than those poured without any addition.

Analysing Austenitic Nickel-Chromium Steels

MR. L. SILVERMAN and MR. O. GATES have put forward in "Industrial and Engineering Chemistry" some interesting methods for analysing 18:8 alloy steels.

A 0.2-gm. sample of steel solution, which has been completely oxidised by the silver-persulphate method, is used for the successive determination of manganese, chromium and nickel. A complete routine procedure recommended for the determination of silicon, niobium, manganese, chromium, nickel, molybdenum and phosphorus is given below.

Silicon and Niobium

Transfer 2 gm. of the steel to a 400-ml. or a tall-form 300-ml. beaker, dissolve in about 20 mls. of mixed hydrochloric-nitric acids, and add 18 mls. of technical (70 per cent.) perchloric acid. Heat to expel the mixed acids and then raise the temperature until most of the chromium has oxidised, but discontinue heating before any of the chromium is boiled out of the beaker. Three converging lines of condensed acid (coloured yellow, not green) are usually seen under the cover glass when dehydration of silica is complete. (Use a no-bump beaker holder for high silica.) Cool somewhat, and add 50 mls. of water to dissolve soluble matter. Heat to boiling to expel chlorine. Remove the beaker from the heat, and when suitably cooled, filter through paper and catch in a volumetric flask (200 or 250 mls.). Wash well with water containing a few drops of sulphuric acid. Change the receiving flask, wash several times with (1+10) hydrochloric acid to remove the last traces of perchloric acid, then finally with water. The paper contains silicon, any niobium if present, and about 0.02 per cent. of retained impurities.

Manganese, Chromium and Nickel

Dilute the volumetric flask solution to the mark. Transfer a 0.2 gm. aliquot to a 400-ml. beaker. Add 5±0.1 ml. of silver nitrate solution, 5 mls. of (1+1) sulphuric acid solution, 0.3 ml. of glacial phosphoric acid, and 20 mls. of 6 per cent. ammonium persulphate solution. Dilute with water to about 100 mls. Heat to complete the oxidation of manganese and to destroy excess persulphate, without boiling. Remove from the heat and cool to 5 to 10 deg. C. Titrate slowly with standard arsenite-nitrite solution (1 min. for first 5 mls. and 0.5 min. for each extra 5 mls.), shaking the beaker above a sheet of white paper. Dilute the solution to 200 mls. with cold water, and add 5 mls. of (1+1) sulphuric-acid solution. Titrate with standard ferrous sulphate solution, using a potentiometer (mercury, mercurous chloride, potassium nitrate with platinum electrode) as indicator for the chromium.

Add 50 mls. of citrate solution, which contains enough chloride to precipitate the silver, and then just enough ammonium hydroxide to dissolve the precipitate, thus adjusting the acidity. Add 2 mls. of the potassium iodide solution, and titrate with standard cyanide solution to the end point for the nickel.

Molybdenum

Cool a suitable aliquot, treat with 15 mls. of 20 per cent. stannous chloride, 5 mls. of 5 per cent. ammonium thiocyanate, 10 mls. of (1+1) sulphuric acid, and 1 ml. of hydrochloric acid (1.2 sp. gr.), then extract the molybdenum by ether, butyl acetate or cyclohexanol, and compare with a standard.

Phosphorus

Use the remainder of the solution or a suitable aliquot. Add 5 mls. of nitric acid (sp. gr. 1.1) and about two drops of concentrated hydrochloric acid, boil down to 50 mls., add molybdate solution and ammonium hydroxide and complete by any approved method.

Reference is made by the authors to selected earlier Papers on the estimation of the respective elements, and the advantages and limitations of other methods are briefly discussed. The procedure recommended by the authors for the determination of manganese and chromium has also been applied to other related types of alloy, *e.g.*, 80/20 nickel-chromium alloys.

Gravity Die-Castings in a High-Strength Aluminium Alloy

(*Continued from page 4.*)

difficulty is encountered with this gravity die-casting, but if the box had to be provided with a bottom, special precautions would be necessary to avoid cracks. Even then it is doubtful as to whether it would be found possible to provide a feed adequate enough to obviate draws in the bottom.

A gravity die-cast housing, also of uniform thickness, but with an internal curved web, is shown in Fig. 4. In this case a sand core had necessarily to be used, since a core of steel could not have been withdrawn. In any case, it must be pointed out, the use of a steel core, even if practicable, would almost certainly have resulted in cracking of the web on solidification. The coring of the stud holes, although adding to the complexity of the die, assists in maintaining uniformity of section and contributes considerably to the successful production of this component.

A part which presents considerable difficulty is illustrated in Fig. 5. First, it embodies sections approximately to the low limit of thickness and, secondly, complications in the die are caused by the need for providing adequate feed to the three long bosses and to the thicker sections on two sides of the end flange. Without a somewhat complex die considerable danger would exist of cold shuts, draws or cracks in the large areas of very thin sections.

Thus it will be appreciated that careful consideration, preferably in collaboration with the manufacturer of the material, must be given to many factors when the production of a given component by gravity die-casting in the material is being contemplated. Nevertheless, where a given design is found suitable, if due regard be accorded to the essential precautions stressed in this article, then no trouble should be experienced in the foundry.

VISCOUNT FURNESS, chairman of the South Durham Steel & Iron Company, Limited, left £3,661,930.

Modern Core Ovens*

By H. M. LANE

Core ovens in the past depended upon natural draft to distribute heat through the oven. The universal fuel was coke, although wood and coal were occasionally used. The oven usually consisted of a brick chamber with a fire in a firebox at the back or below the floor of the oven. Later gas and oil were used to heat the ovens, but the practice of depending upon natural draft to distribute the heat persisted for a long time.

Before discussing further the evolution of the modern oven, it might be well to restate some of the fundamentals of core baking in order that the steps taken by oven designers may be more readily understood.

Cores may be green-sand cores, which are the same composition as the mould and require no drying, or they may be dry-sand cores, bodies of sand held together with a colloidal substance, called a binder, that can be dried to hold the sand grains together. The binder must be of such a nature that it will burn out and permit the sand to collapse as the metal cools.

Selection of Core Binder

Different metals have varying amounts of latent heat that is released in cooling. The melting temperature also has an influence on the amount of heat available to break up or release the binder. Hence, the binder used must be selected to suit the metal being poured. Steel has the highest melting temperature and a high latent heat. On the other hand, aluminium releases much less heat per pound or cubic inch of metal.

In grey-iron practice, where a large number of cores are required for small and medium-sized parts, some form of binding oil is the material most commonly used. The so-called drying oils, or paint oils, are generally employed, such as linseed, China wood or twig, soya bean, etc.

In this class of work the sand that requires the least binder is a sand of rather uniform grain size, with the grains as nearly round as possible. The surface required on the casting determines the grain size and this, in turn, determines the amount of binder required. The greater the number of contact points in the sand, the greater the amount of binder required.

Types of Binders

For large outputs some form of liquid binder gives the fastest core production; but oil and certain other binders do not give sufficient green strength to enable the core to stand up before and during drying. Hence, some kind of dry or solid binder is added for green strength. This may be flour, starch, dextrin, cereal binder (a modified starch or dextrin), bentonite or clay.

Addition of such material acts like shortening in pie crust and reduces the efficiency of the oil. Hence the best mix for efficient production is a compromise between grain size for surface and green strength requirements. Where cores do not have any upstanding parts and are supported in dryers, it is sometimes possible to bind well over 100 parts of sand with one part of oil. As grain size becomes smaller to give the desired smooth surface, and as dry material is added to give green strength, the oil-sand ratio may be reduced to as low as 30 parts of sand to one part of oil.

In heavy work in grey iron, sand, pitch or black compound binders may be used. Recourse may also be had to a combination of clay or bentonite, or a liquid binder, such as waste sulphite liquor products. The latter tends to increase the action of the clay as a binder and at the same time helps in releasing the core when the casting is poured. These liquid binders are sold under a number of trade names. Molasses is also used, especially in steel practice, to help the green strength and the release of the core from the casting.

In brass castings resin is frequently used because of the smooth surface it leaves and the fact that it burns out and releases the sand readily. Flour, starch, molasses, dextrin, cereal binder, sulphite liquid compounds, and similar binders, absorb moisture on storage and lose strength and are likely to cause blows. Oil, pitch and resin cores do not absorb such quantities of moisture as to prevent their being stored for a reasonable time.

The use of sand with the coarsest particles will reduce the number of contact points in a given core and so reduce the drying time and improve the venting properties of the core in the mould.

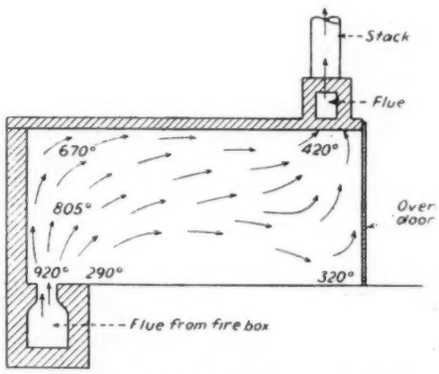


FIG. 1.—DISTRIBUTION OF HEAT IN AN EARLY TYPE OF CORE OVEN, SHOWING A VARIATION OF 139 DEG. C. BETWEEN DIFFERENT PARTS OF THE OVEN.

If an oil-sand core is dried to a light yellow it will be strong, but it gives off such an excess of the gas when the mould is poured that a core blow is likely to develop. If baked to a light chocolate colour, the strength will be reduced slightly, but from 60 to 75 per cent. of the gas given off from the core will be eliminated and this, in turn, will reduce the possibility of core blows.

Cores for magnesium must be made from fine sand of uniform grain size and must contain sulphur and other inhibitors to prevent the oxidation of the metal. So-called sharp sand, such as is used in making concrete or plaster, was formerly much used in the foundry. The present tendency, however, is towards sands having rounded grains.

Cores for Grey Iron Castings

In most production foundries turning out grey iron or malleable iron and making motor-vehicle castings, pipe fittings, radiators or a similar line, oil-sand cores find the widest use. The standard strength of the cores varies from 50 to over 100 lbs. per sq. in., and the oil to sand ratio varies from 1:50 to 1:100. Flour cores may be made with as low as one part of flour to 20 parts of sand, up to one part of flour to 30 parts of sand. Molasses is generally used with a clay or moulding sand mix, and the ratio of molasses to sand may vary from 1:20 to 1:50 or more. The same is true of glutrin or other waste sulphite liquid products.

Cereal binder, dextrin (core gum) or starch may be used to give green strength to oil-sand mixes, or as a binder with mixes containing clay or moulding sand. The ratio of binder to sand may vary from 1:20, up to 1:40 or 1:50. Resin mixes generally run from 1:20 to 1:50.

For very thin castings it is necessary to have cores that will crush easily. On the other hand, where cores have to endure the cutting action of flowing metal, very strong cores are necessary. In normal practice, core strengths vary from 4 or 5 lbs. per sq. in. up to as high as 150 lbs. per sq. in.

Classification of Binders

Core binders may be classified as follows:—Oil binders, water soluble binders and pitch and resin binders.

Oil binders form a hard film when oxidised, which tends to bind the sand. These binders give the best results when baked between 215 and 232 deg. C. Above 260 deg., the oil is destroyed, while below 170 deg. the oxidation is extremely slow.

Water soluble binders contain quantities of corn starch, molasses, glue, wheat flour and dextrin, mixed with water. The ideal baking temperature for this type is 170 deg. C.

Pitch and resin binders are finely pulverised and mechanically mixed with core sand. During the baking operation this mixture is melted and it hardens again during cooling. The most efficient baking temperature is 170 deg. C. Combinations of core binders, sold under various trade names, generally contain drying oils, resin and mineral oils, and are best baked at 204 deg. C.

During baking the heat must perform the following operations: Raise the core plates and sand to the baking temperature; raise the moisture, about 6 per cent. of the sand, to boiling point; evaporate moisture and volatile matter in oil binder, and oxidise the oil in core binder.

Obviously, it is necessary that an oven be heated uniformly, as otherwise all the reactions noted in the preceding paragraph may be taking place at the same time in different parts of the oven. Another important point is that the oven atmosphere must contain enough oxygen to oxidise the binder.

It should be borne in mind that as much heat is usually required to drive off the moisture as is needed to bring the sand up to temperature. A tremendous amount of air is needed to do this, and, unless it can be recirculated, the result will be a large and costly stack loss. In addition to keeping the stack loss low, recirculation prevents too rapid removal of moisture from the core exteriors which would result in skin-drying or case-hardening.

Early Tests

About 30 years ago, a test was run on what was then considered a modern oven in an attempt to study the distribution of heat within the oven. Holes were drilled through the oven walls and 21 thermocouples, long enough to reach the centre of the oven, were inserted. Heat entered this oven through a flue under the floor at the back and the gases were taken out through openings in the side walls on the floor level at the front

The highest temperature (see Fig. 1) recorded after the core bogie had been in the oven approximately 2 hrs. was on the thermocouple over the inlet flue at the back of the oven. This was 493 deg. C., a dull red. Such a temperature would burn any core. Half-way up the oven the temperature had dropped to 429 deg. and at the top at the back it was 354 deg. This was a drop of some 139 deg. in a vertical height of less than 7 ft. of open oven, where no baking was taking place. The coldest point in the oven was found 2 ft. from the hottest point.

As the hot gases rose along the back of the

* Extracted from "The Iron Age." The author is associated with the Paul Maehler Company, Chicago.

oven, some of the gases entered the core car and became colder, heavier and loaded with steam. These colder gases started down to the floor and tended to return along the floor towards the heat flue. It was this current of cold gases flowing to the back that mixed with the hot gases from the four openings from the flue and caused the drop of 139 deg. in temperature during a rise of less than 7 ft.

Incorporation of Fans

Realising the impossibility of properly baking cores with such an unequable heat distribution, oven designers turned their attention toward mechanical methods of heat distribution. In one early experiment, a fan was installed at the back of the oven. While this arrangement did give more uniform drying of the cores, it was not wholly satisfactory because of the high cost of maintaining the long fan drive shaft required.

The next step was the installation outside the oven of a fan with one air line leading to the ash pit to give forced draft and the other line running to the flue beyond the fire. This design, which tended to lower the flue temperature to a safe baking level, was patented and installed on many ovens. However, it was not wholly satisfactory, as it required careful adjustment of the dampers. Improper adjustments occasionally resulted in the melting of the walls and roof of the firebox. To overcome this, the pit was enclosed and put under about 2-in. water pressure, with the firebox inside the pit.

The next step in the evolution of the modern oven was the use of a fan for exhausting gases, and a form of recirculation which took some of the gases from the outlet flue and introduced them into the inlet flue beyond the fire. Then followed the depressing of the oven floor to the bottom of the fire flue. This, together with modifications in openings in the oven floor, resulted in an increase of 15 per cent. in oven efficiency.

At about this time, core oils made with the so-called rosin oil were introduced. Not being a binder, this oil evaporated from the cores and deposited in the flues, where it often caught fire, burning out the exhaust fans. To overcome this liability, the fans were taken out of the stack and small high-pressure fans were used to blow air into the base of the stack to induce draft.

In succeeding years, this design was further modified and improved. Fireboxes were built in the back of the ovens above the floor and natural draft was used for the fire. Fans were used then only to force the hot gases about the oven. Research was also conducted on the efficiency of various fuels.

When oil was used, the burner was sometimes placed at one end of the flue, or, in the case of a large oven, at the end of trenches under the core-bogie centre along the oven walls. In forced-draft ovens the burner was occasionally located in the upper part of the firebox. A combustion chamber of refractory slabs was also used, with dampers to control the air introduced about the burner. In most of these cases, however, excessively high temperatures were encountered over the openings in the oven floor.

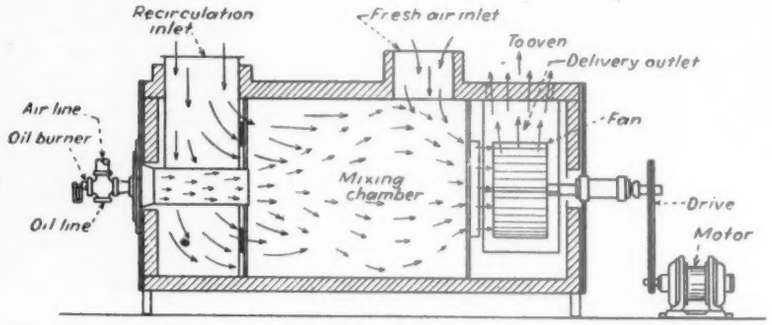


FIG. 2.—SECTIONAL VIEW OF MAEHLER RECIRCULATING TYPE OF CORE OVEN HEATER.

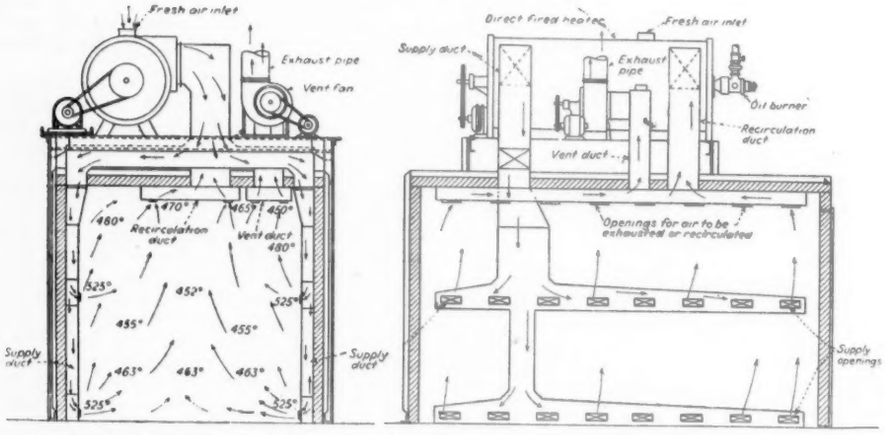


FIG. 3.—ARRANGEMENT OF DUCTS IN A MAEHLER OVEN TO GIVE EVEN DISTRIBUTION OF HEAT.

The most common arrangement when gas was employed was a long perforated pipe on each side of the oven. Occasionally the pipes were put in trenches below the floor. In some installations, air under pressures up to 16 ozs. was used to bring the gas through the burner and into the pipe. Gas burners, as a rule, gave better heat distribution than oil burners in trenches. However, it was still not possible to obtain uniform temperature in all parts of the oven.

Coke-fired auxiliary air ovens gave the best results because of the greater volume of hot gases circulated. But, due to the high-temperature gases which were not diffused and carried off by ample volumes of air, maintenance of firing chambers was costly and excessive temperature variations took place in the oven.

Air-Heater System

The greatest efficiency in core and mould drying has been produced by an oil- or gas-fired air-heater of the type shown in Fig. 2. This unit develops a constant source of heated air at moderate temperatures. The air and products of combustion are constantly fanned into the oven and returned in a major percentage of its volume to the heater for reheating and revitalising with fresh oxygen.

The efficiency of this type of heater is enhanced by properly designed air ducts which convey the heat through distribution ducts to the oven, the recirculation ducts and a separate venting system (see Fig. 3). The proportion of vented air to the volume of air produced by the air-heating system is approximately one air volume vented to nine volumes recirculated. An effective, rapid circulation is thus produced in the oven.

The heat output and its effect upon the charge in the oven are computed on established engineering formulæ, and the air directioned in an intelligent manner. There are no temperature variables that are excessive. Small and large cores can be baked in the same charge and are not overbaked even if baked too long.

The air-heating system has no pits or firing trenches, and oven floors are flush with the foundry floor.

A suggestion of the efficiency possible from such an installation may be had from results obtained at a large grey-iron foundry where an old brick oven was recently converted by installing an oil-burning air-heater. The oven is 22 ft. 6 in. long by 7 ft. 3 in. wide by 8 ft. 10 in. high. The core bogie is 17 ft. 8 in. long by 6 ft. 10 in. wide by 8 ft. high. The core load is 9,000 lbs.; steel load, 10,000 lbs.; fuel input for 4 hrs. of operation is 25 galls. of No. 3 oil. The net efficiency is 360 lbs. of cores per gall. of oil on work consisting of large cores for paper machinery.

Production and Distribution of Hematite Pig-Iron

NEW CONTROL SCHEME

As from December 29, under a detailed scheme which has been drawn up by the Iron and Steel Control, all deliveries of hematite pig-iron will be allocated and producers nominated. This step is necessary as a result of changes in the production programmes of some hematite producers and the additional necessity of tying up deliveries of imported iron with home-produced iron.

The scheme will guarantee more effective distribution and will be welcomed by consumers, ensuring, as it does, a specific weekly tonnage. All the varying qualities of hematite have been covered in order that special requirements can be safeguarded.

Ordinary commercial contacts between buyer and seller will remain in so far as contracts and specific delivery details are concerned, although the tonnage indicated by the Control will represent a maximum for the period, unless there are special circumstances requiring review.

It is understood that hematite will only be released for purposes where no other alternative material can be substituted. This decision will affect a number of ironfoundries. A supply of low-phosphorus foundry iron will be available, although a strict watch will continue to be kept on the consumption of this quality. Refined irons as a further alternative to hematite are in reasonable supply.

The output of phosphoric foundry iron is maintained at the consumption level, and an adequate margin for a working stock is now being granted to all those consumers on essential work. Very little iron, if any, is being released for the production of castings of a domestic nature.

The Acid Bessemer Process of 1940

By H. W. GRAHAM

(*Continued from page* 418, *vol.* 63.)

Efforts are now being directed to full exploration of the exact length of afterblow that is most favourable for each grade of product and each phase thereof. Where various quality factors in a single grade call for different periods of afterblow, the best possible compromise will be selected. In this way progress may be achieved toward a degree of uniformity never before reached in Bessemer operation.

With the instruments installed for determination of the end point, months were spent in checking the blower's determination. Then gradual advantage was taken of the instrumental determination until finally blowing was based upon the instruments, very little being left to the judgment of the blower. To show the results before and after the time when dependence was first placed on the "electric eye," Figs. 4 and 5 have been prepared. Fig. 4 is a conventional frequency diagram, one line of which shows the performance of blowers based on their own judgment of the flame reactions. The period involved covers three months with a total of 943 blows observed.

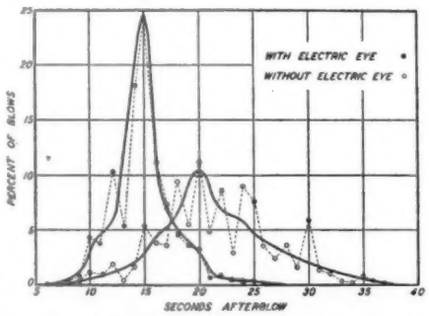


FIG. 4.—FREQUENCY DIAGRAMS FOR 3 MONTHS' OPERATION WITH, AND 3 MONTHS WITHOUT, ELECTRIC EYE.

One year later the instruments were being depended upon to determine the end point, and the frequency diagram for a second three-months' period is also shown in Fig. 4, covering 2,781 blows observed. It is evident that the instrumental determination of the end point is yielding a much more uniform performance. The shift of the "electric eye" data to the left is caused merely by the fact that the specified afterblow has deliberately been made somewhat shorter.

Since conventional frequency diagrams are qualitative in character, the data of Fig. 4 are presented in quantitative fashion in Fig. 5 by taking the median point of each of the two groups of data as a zero point and constructing cumulative diagrams therefrom. The time element of Fig. 5 is to be construed as a plus and minus quantity; that is, 5 secs. on the diagram covers a spread of time of $\pm 2\frac{1}{2}$ secs. or a total interval of 5 secs. Fig. 5 indicates, for example, that within a total spread of 5 secs. the installation of the photocell equipment improved the uniformity of the performance from 35 to 64 per cent. In the second three-months' period 90 per cent. of the blows were within a total spread of 10 secs.

It would unduly extend the length of this Paper to attempt to give any appreciable part of the data already available as to the effect of this improved uniformity on manufacturing and metallurgical conditions. Briefly, it contributes to a narrower range of oxidation conditions, fewer off-heats, savings in ferromanganese, sounder interior of ingots, smaller surface defects, better yields, and narrower ranges of physical properties and workability.

Temperature Control

The importance of temperature has been referred to previously in this Paper, but it should be said here that somewhat better performance has latterly been experienced, which has in part depended upon the photocell equipment. Although this equipment is primarily intended for end-point determination, it can be used to assist in temperature control. Much effort is being directed to closer temperature control, but publication of specific data must wait until changes now being made in pyrometric equipment and methods have been more completely developed.

Design and Maintenance

The struggle for advancement in Bessemer steelmaking to the end of generally improved quality and a high degree of uniform reproducibility involves many details of a more or less mechanical character. This is exemplified by

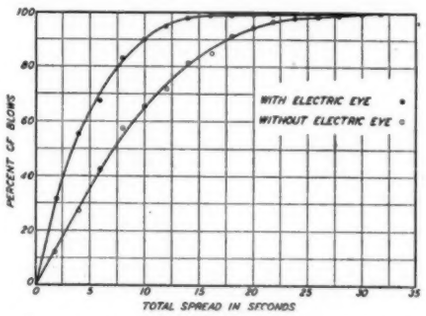


FIG. 5.—QUANTITATIVE FREQUENCY DIAGRAM REPEATING DATA GIVEN IN FIG. 4.

variations in the length of time required from the moment the turndown mechanism is set in motion to the moment when all tuyeres are clear of the bath. The blower may, with or without instrument assistance, accurately gauge the status of the flame, but many factors may influence the interval required to clear the tuyeres. Power-supply pressure, either electric or hydraulic, may vary appreciably from moment to moment owing to fluctuating demands from other equipment supplied by the same system. Vessel linings erode and wear away, "kidneys" and vessel skulls build up or burn away, thus increasing or decreasing the speed of rotation of the vessel.

A study of variation in the turndown interval, involving some hundreds of blows, was made on two vessels, one operated electrically and the other hydraulically. A short series of successive blows was selected from this study to show in Fig. 6, which indicates variations that may well be unfavourable to quality and uniformity if the operating crew are not alert to compensate for changes in the rate of vessel rotation. Obviously, new converter installations should be designed, and existing plants altered, to provide very liberally powered rotating mechanism, fed by a power supply as separate as may be possible from other equipment that might produce fluctuations in pressure or voltage.

Fig. 6 makes clear that even if a given blow is turned correctly with reference to point B in Fig. 1 it may still be blown some seconds more or less than it should have been, if the blower has improperly gauged the rate of speed of rotation of the vessel. Other parts of this Paper, for instance, Fig. 2, show that a variation of this order might unfavourably affect the quality of the product.

Gradual erosion of the lining or slow building up of vessel skulls will produce gradual changes, which can be compensated for by an alert blower, but he can hardly be held responsible for sudden fluctuations in power supply such as inevitably will occur if other heavy equipment is fed from electric or hydraulic lines used to rotate the converter.

This situation has been discussed at some length because it illustrates one of many more or less similar reasons for the diminishing position of Bessemer steel. In a distant customer's plant a complaint is registered on a delivery of Bessemer steel, and customer, salesman, and manager take the incident as one more count against Bessemer steel and the Bessemer blower —whereas the cause may really be hydraulic lines of too small a diameter, a detail certainly not chargeable against the process but rather the responsibility of plant management and plant engineer.

If the Bessemer process is to return to its proper place in the steelmaking industry, different thinking and a different attitude will be needed on the part of all concerned—manager, engineer, and operator alike. It is not hard to see what this changed attitude will

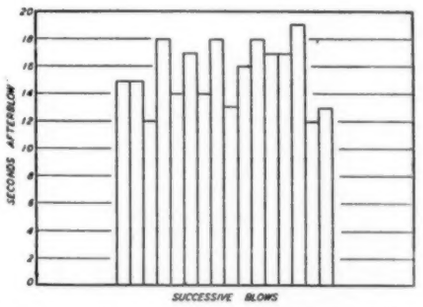


FIG. 6.—VARIATIONS IN LENGTH OF AFTERBLOW DUE TO MECHANICAL CAUSES.

have to be. There are few real mysteries or obscurities in the picture. The attitude required is merely this: The Bessemer process can be restored to its position if those involved will commit themselves to the improvement of control and to the reduction of causes of variation —to the extent that represents good practice in maintenance and operation of equipment in general, and if they will further support the metallurgist in continued study of those phases not yet entirely understood.

This is a very simple policy and one that has been in effect in the open-hearth plant for some years but that as yet is not represented in Bessemer operation. An example of this situation is to be found in the air-blast supply for a Bessemer converter. True, there remains to be done considerable study of the relation of blast supply to the various features of the Bessemer process; but reasonable control and even investigation is made difficult, if not impossible, in installations where two or more converters are blown from a common main, and in which blast leakage that is serious in volume and varying in degree is tolerated around the converter bottom. The steelmaker would not drive his own motor-car with petrol dribbling from a leaky carburettor. He would get it repaired or install a modern and well-designed unit. If he will apply the simple policy of good equipment, well maintained, the Bessemer process can be revived. If he will not do so, the Bessemer process will continue its

steady movement towards extinction. If this policy is simple and clear, its complete application may be neither easy nor inexpensive. It may require costly revamping of blowing equipment, periodical refacing of converter bottoms, and attention to a host of other details.

Oxygen Control

In dealing with oxygen, the tendency of the Bessemer process to be "automatic" is of appreciable assistance to the operator and to the metallurgist. Granted substantially uniform iron and air blast, control of temperature will not be too difficult and the slag will be reasonably uniform in volume and analysis. To the extent that such conditions prevail, the degree of oxidation will depend entirely upon the time at which the blow is turned down. There is therefore control of degree of oxidation to the extent that there is control of the end point. Fig. 4 shows that instrumental determination of the end point is of great assistance in narrowing variations in the length of the afterblow and therefore contributes to control of the degree of oxidation. In regard to individual blows, however, there are in practical operation conditions of variation that make it improper to conclude that all blows should be of some exact and uniform length of afterblow.

The length of afterblow proportionate to a given degree of oxidation, as necessary in arriving at a uniform manganese efficiency, is affected by weight of iron charged, silicon and manganese content of the iron, and temperature of the blow; but the facts concerning these influences are not yet fully developed and in any event a full discussion of them is beyond the scope of this Paper.

Obviously, too, the rate of oxidation reactions will be influenced by the rate at which oxygen is supplied. Since it is common practice to block off or "blank" such tuyeres as become badly eroded during the life of a converter bottom, the number of open tuyeres is gradually decreased and, for any given pressure, oxygen is supplied at a progressively slower rate as more and more tuyeres are blanked, requiring a proportionate increase in the length of the afterblow.

It is assumed that adequate control exists to maintain a constant blast pressure. And, as previously pointed out, attention must be paid to any condition that affects the rate of rotation of the converter from an upright position to the position where the tuyeres are clear of the bath and oxidising action is stopped.

The foregoing discussion may suggest a somewhat more complex and difficult situation than actually exists. If for the best results on any given quality phase of a given grade of steel the optimum length of afterblow is found to average, say, 16 secs., corrections for factors of variability will not usually change this length of afterblow outside of a range of 14 to 22 secs.

Because of the broad scope of the present Paper, it would not be practicable to give complete data to support each statement or conclusion that is made. Perhaps in later publications individual phases of these Bessemer problems may be more fully discussed with complete and appropriate data. In presenting the broad conception that this Paper is intended to set forth, endeavour is made to accompany each phase with an example of the investigational data upon which thinking has been based.

In accordance with this procedure it appears appropriate to show data as to the effect of varying relationship of carbon content at the end of the blow to the iron oxide content of the vessel slag, as in Fig. 7, which is considered to be self-explanatory. In the Bessemer process oxidation conditions are really quite precise, and the degree of scatter in the points of Fig. 7 is present because the data have not been corrected for the effect of known variables. Presumably if the iron oxide in the steel were determined accurately, there would result a very smooth curve for the carbon-iron oxide relationship. By inference, Fig. 7 shows the increase of iron oxide in the slag for increased length of afterblow, since the carbon content decreases as the afterblow progresses.

Nitrogen Control

One of the characteristic features of Bessemer steel is its rather high nitrogen content. Beginning with a pig-iron containing from 0.002 to 0.006 per cent. nitrogen, finished Bessemer steel ordinarily will contain from 0.011 to 0.020 per cent. nitrogen with scattered blows outside of these limits. This fact has been known for years, but the physical chemistry of nitrogen in Bessemer steel has not been adequately explored and the factors governing the form and amount of its occurrence are even now not well understood.

Support can be obtained for the idea that nitrogen solubility is inversely proportional to the carbon content, increasing as the carbon is eliminated from the bath. The data available in general support this conclusion, but the situation is clouded by the fact that the temperature increases as the carbon decreases. Superficially, too, one might think of nitrogen increasing with longer blowing time, but this neglects all thought of saturation limitations. It is generally true that longer blowing time usually means higher nitrogen, but it also usually means higher finishing temperatures, since the longer blowing time is largely caused by increased silicon content with consequent higher temperatures because of the greater amount of the heat-producing element present.

At the present writing, it is difficult to make a simple unqualified statement that could stand unchallenged as being theoretically correct in presenting the conditions governing the nitrogen content of Bessemer steel; but chemical composition in general, and particularly carbon content, is generally fixed by the physical properties and workability desired and is not subject to change merely to produce a higher or lower nitrogen.

A tremendous weight of data is available to show that higher nitrogen contents accompany increased temperatures, and for practical purposes it is dependably sufficient to say that nitrogen can be controlled to a considerable extent by control of temperature.

The relationship of nitrogen content to the temperature of the finished blow is apparently so definite as to make this feature outstanding, as shown in Fig. 8. These data were based upon optical pyrometer measurement of temperature and the scatter of the points may more likely be due to incorrect temperature measurements than to any true deviation from the nitrogen-temperature relationship. In fact, if a given Bessemer blow is high in nitrogen, the metallurgist may with little error assume that it was a hot blow even if he has no temperature data.

For practical purposes, therefore, it is adequate to consider that nitrogen is directly proportional to temperature. One is inclined to speculate a little as to whether the increased nitrogen taken up as the temperature rises is purely a matter of solubility of nitrogen in molten iron, or whether there is present some chemical effect. There would be a certain plausibility to the hypothesis that higher temperature favours the formation of certain nitrides that may form only partially or not at all at lower temperatures. Unfortunately, there is as yet available no real information as to the forms of occurrence of nitrogen in steel, a subject that some day may be found to be of the utmost importance.

In actual operation, by controlling the blow as much as possible toward the cold side, Bessemer steel can be made with nitrogen considerably below the normally expected content. How far the Bessemer operator can go in suppressing the nitrogen content by blowing at lower temperatures will depend upon the skill of alert crews in fast uniform procedure, having available iron of closely controlled analysis and temperature, using well-insulated ladles and all similar aids. This whole situation is subject to further study and development.

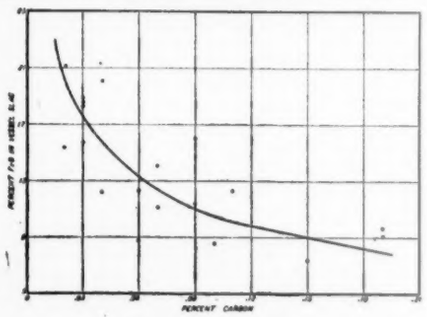


FIG. 7.—EFFECT OF VARYING RELATIONSHIP OF CARBON CONTENT TO IRON-OXIDE CONTENT OF VESSEL SLAG.

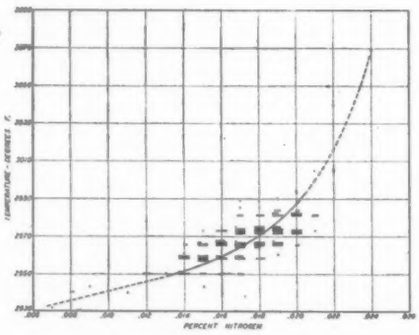


FIG. 8.—NITROGEN AND TEMPERATURE RELATION OF FINISHED BLOW.

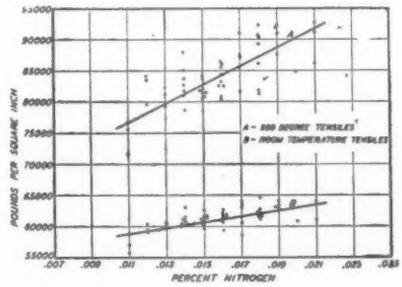


FIG. 9.—NORMAL AND THERMALLY-AGED TENSILE STRENGTH IN RELATIONSHIP TO NITROGEN CONTENT.

Physical Properties

The earlier portions of this Paper made no effort to describe the general aspects of existing Bessemer plants or operation thereof, the intent being merely to point out wherein modern requirements call for modification of existing facilities and operating methods. Likewise, in referring to physical properties, it is considered illogical and impracticable to discuss the general subject in full, but it is desired to point out that the "modernising" of the physical properties of Bessemer steel resolves itself into the task of understanding and evaluat-

(*Continued on page* 16.)

Vitreous Enamelling Section

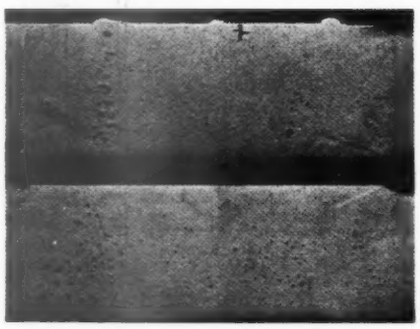
Relation of Defects in Enamel Coatings to Hydrogen in Steel

By C. A. ZAPFFE and C. E. SIMS

(*Continued from page* 370, *vol.* 63.)

One should not expect entrapped air, if dry, to cause surface defects, because both oxygen and nitrogen react with iron at enamel-firing temperatures to form solid phases. It should be pointed out that the use of sand-blasting instead of pickling, although successful in the test cited last month, cannot be depended upon for strict elimination of hydrogen-caused defects for reasons already explained. In the case referred to, it was known that hydrogen was not present in the discontinuity in the beginning of the test.

The tests clearly illustrate the reason that enamel defects are often found overlying blowholes, pipe, porous metal, and inclusions; in fact, any heterogeneity that is sealed within the steel, but near enough to the surface to be effective. Defects in the steel that open on to the surface do not cause blistering unless liquids become entrapped in them because the defect is an open hole and cannot trap hydrogen.



Red iron oxide Graphite Empty

FIG. 23.—PLATE WITH SEALED HOLES CONTAINING IRON OXIDE, GRAPHITE AND AIR RESPECTIVELY, FIRED WITH WHITE COVER COAT.

(4) Effect of Inclusions in Steel

An inclusion in steel, of course, is a discontinuity, and may act exactly and solely as a cavity in which molecular hydrogen may precipitate. It has been shown by experiment that the hydrogen atoms recombine so instantaneously upon leaving the metal lattice that it is often difficult to obtain a chemical reaction with other elements. Nevertheless, if there is good contact, reactions are especially favoured, particularly with oxygen, and the resulting hydrogen-containing products naturally respond to temperature changes differently from molecular hydrogen. The greatest difficulty in identifying defects as hydrogen functions has perhaps resulted from these retentive chemical actions of unknown impurities in the steel. As a result of these complicating reactions, hydrogen may be released at almost any temperature, depending both on the physical and the chemical nature of the many components that differentiate steel from iron.

In an attempt to demonstrate some of the anomalous effects produced by impurities in steel, three types of test were performed in the present research in which the retaining conditions were physically and chemically different. First, artificial and lightly-packed impurities with poor metallic contact were studied. The three holes in a customary test-plate were arranged as follow:—(1) Sealed empty; (2) tamped full of graphite and sealed; and (3) tamped full of iron oxide (red rouge) and sealed.

The plate was prepared in the usual manner, so that hydrogen from pickling would precipitate in the three cavities. Firing a blue ground coat showed no trace at all of the underlying cavities. The piece was re-fired twice without renewing application of the slip, but no evidence of hydrogen defects appeared, in sharp contrast to the specimen shown in the previous figures. A white cover coat was then applied, and firing brought the results shown in Fig. 23.

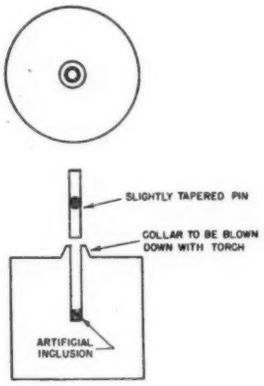


FIG. 24A.—SKETCH SHOWING METHOD OF INTRODUCING INCLUSIONS.

The specimen had been lightly pickled purposely to favour differentiation of any effects imposed by the enclosed impurities on hydrogen re-solution during firing. As a result, the molecular hydrogen in the right-hand hole has been completely dispersed by the several firings, so that the best surface on the whole plate is that which directly overlies this third hole. That area corresponded to the thin section of the wedge in Fig. 16 after the occluded hydrogen had been removed, and it is significant that the hydrogen occluded during this shorter pickling period was insufficient to blister the ground coat. Furthermore, the distance that the hydrogen has diffused through the length of the plate after leaving the cavity is evidenced by the blisters that occur at either side of the hole. Defects on the surface have thus completely reversed their characteristics around this cavity. The thinnest metal section was the most immediate exit for trapped hydrogen and became in turn the first section to be free of the gas, and therefore the first to "boil down." The thicker sections received the laterally diffusing gas, and the train of blisters marks its progress.

The central cavity, which contains graphite, evidences a slightly less advanced stage of hydrogen removal. This should be expected, because hydrocarbons would form, but would be largely dissociated at the firing temperature. Hydrocarbon that dissociated in direct contact with the iron may have provided immediate escape for the nascent hydrogen, but in such a large, lightly-packed mass, it is more likely that molecular hydrogen resulted from the decomposition. The gas would then behave much as that in the right-hand cavity except that resolution would be slightly retarded by remanent carbon-hydrogen bonds. The evidence shown in Fig. 23 supports this reasoning.

The left-hand hole, which contained red iron oxide, is sharply delineated on the surface with blisters, and shows that hydrogen has been strongly retained, most likely by reaction with the oxide to form water vapour. The wide dispersion of small blisters attests that some gas escaped during the first firing just as it did from the other holes, so it must be assumed that molecular hydrogen was also present and that dissociation (in contact with iron) of water vapour above 800 deg. C. is slower than the dissociation of molecular hydrogen. Alternatively, dissociation of the water vapour to reproduce iron oxide must deposit this iron oxide, of course, on the metal surface, where the reaction occurs, and would thereby form a layer that would retard further reaction until the necessary diffusion had occurred.

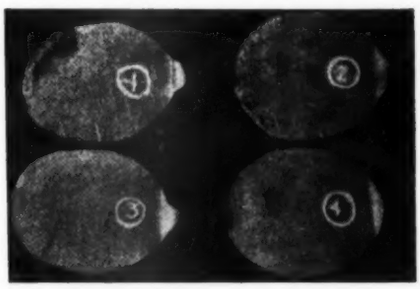


FIG. 24B.—PIECES AFTER FORGING.

The curious lack of blistering in the ground coat of this specimen is significant in regard to the little-understood relation of cover-coat blisters to ground-coat behaviour. That the gas evolved continuously since the first heating is clearly indicated by the dispersion of blisters just discussed. There is evidently a great difference in refractoriness, viscosity and permeability to hydrogen between the ground and cover coats. The marked permeability of this particular ground coat to hydrogen perhaps ex-

plains why some investigators have claimed that blistering can be eliminated by manipulating properly the composition of the enamel and that the length of the pickling period often affects blistering. It may also explain why some persons have supposed that blisters in a cover coat are caused by reaction with the ground coat and that "reboiling" is not related to "primary boiling." This does not mean that reboiling is always just a repetition of the primary boil, for in many instances the steel is initially free of critical amounts of hydrogen and becomes "loaded" for the first time when chemically combined water in the enamel of the first coat or hydrogen-containing furnace gases react with the iron. Further discussion of reboiling will be reserved until later.

The contrast of blistering activity in the test just discussed is interesting, for if a certain "fraction" of hydrogen-retaining impurity predominates in a dirty steel, an enamel may be satisfactorily used whose firing temperature is

FIG. 25.—PLATE 1 (FIG. 24B) OVERFIRED WITH BLUE GROUND COAT AT 1,050 DEG. C.

not the temperature at which the impurity releases its hydrogen. This selective effect of impurities is even better illustrated in the following experiments.

It was stated that good contact of the impurity in an inclusion with the atomic hydrogen at the instant that the gas leaves the metal lattice is important for reaction. As the test just discussed plainly lacks good contact of impurity with metal, a second group of tests was made wherein the artificially introduced inclusions were hot-worked into the steel, thereby more closely simulating natural conditions. In the first tests of this group, an ordinary 2-in. round steel bar was cut into four 2-in. lengths, and these were drilled as shown in Fig. 24A. In the four specimens were placed 0.1-grm. samples, respectively, of the following impurities:—(1) Natural tephroite $(MnO)_2SiO_2$; (2) synthetic fayalite $(FeO)_2SiO_2$; (3) open-hearth slag with an analysis of FeO 24.9, Fe_2O_3 11.0, SiO_2 9.5, Al_2O_3 1.6, CaO 35.9, MgO 7.8, MnO 6.6, and P_2O_5 1.3 per cent.; (4) FeS mixed equally with MnO_2.

Small quantities were used to simulate natural conditions. Before inserting the powders, the holes were cleaned with dilute sulphuric acid, washed with distilled water, rinsed with dilute sodium carbonate solution, and dried with acetone. Tapered pins made from the same steel were treated similarly. After inserting the powders, the pins were peened, and the steel flange was welded over with a torch. No welding rod was used. The pieces were immediately placed in a furnace at 1,300 deg. C., annealed for one hour, and were forged as shown in Fig. 24 B. After shearing the stubs, the plates were heated in a furnace to 1,100 deg. C. and were rolled in two passes to about 0.10 in. in thickness. They were then clipped to a smaller size, as the location of the inclusions could be roughly predicted.

The plates were pickled for 25 mins. to ensure obtaining the severe hydrogen conditions that characterised the specimen in Fig. 19. The four sheets were fired at 870 deg. C. with blue ground coat, but no defects whatever appeared. Plate No. 3 was fired twice for a total period of 15 mins., but no defects became visible. Plate No. 1 was reheated to 600 deg. C. in an unsuccessful attempt to develop fishscaling and was then further heated to 1,050 deg. C., where the enamel burned badly but did not reveal where the inclusion might lie.

All four plates were de-enamelled in sulphuric acid and pickled until blisters arose over each inclusion (see Fig. 26). Comparing Fig. 25 with plate No. 1 in Fig. 26, it was evident that the location of the inclusion was not revealed by firings at 600, 870, and 1,050 deg. C. The poor appearance of blistering in plate No. 4 is undoubtedly due to depletion of the impurity by reaction of the oxide and sulphide to form a partially diffusible gas. Except for this one semisulphide inclusion, the impurities are predominantly oxides, and there are indications that these oxides have effectively restrained hydrogen from appearing in deleterious quantities during firing. Of course, the permeability of this ground coat was demonstrated in a previous test, and, as in Fig. 23, a denser coating might well blister also in the present test. Nevertheless, the ground coat and the pickling period were the same as in the test shown in Fig. 19, and yet no blistering has occurred. Fig. 26 shows that all of the inclusions were in gas-tight pockets and that they occluded hydrogen during pickling.

Another test of the hot-rolled impurity type was made wherein the three holes in a customary plate were filled with silica and sealed, much as in the specimen shown in Fig. 23. The plate was heated to 1,175 deg. C. and was reduced 50 per cent. in two passes through the rolls. Firing blue ground coat on this specimen also failed to show any surface evidence of the underlying cavities and impurities.

An effect of impurities in steel on hydrogen retention has been shown for the two cases of (1) porous metal with loosely-packed impurities and (2) forged and rolled inclusions. The third and last case involves the effect of carbon in steel on enamelling defects and will be considered separately and at length because it is apparent from the literature that a satisfactory understanding of the relation has not yet been reached.

(5) Effect of Carbon in Steel

It is not surprising that shop observations on blistering and boiling effects have been interpreted as results of carbon-oxygen reactions rather than primarily as hydrogen functions, for carbon and hydrogen are so closely associated in steel that it is most difficult to disentangle their individual activities. It must be admitted that carbon will reduce oxides in the enamel to some extent during firing and that the oxidising action of steam must oxidise some carbon in the iron as well as the iron. The preponderance of hydrogen, however, theoretically liberated by these reactions and found by spectrographic and by microgas analysis suggests that carbon-oxide gases may not deserve the position of major importance granted them by recent American writers. It is interesting that as early as 1912, one investigator decided that blisters were due to gases in the steel and "also" to gases resulting from the reduction of oxides in the enamel by carbon in the steel.

In the carbon-oxide theory, no account is taken of hydrogen. The argument further weakens when it is shown that steel with 0.01 per cent. carbon reboils as badly as 0.12 per cent. carbon steel and that reboiling not only depends on the atmosphere of the furnace but that gases containing hydrogen, *viz.*, CH_4, H_2O, H_2S, NH_3, H_2 and commercial fuel gases, cause severe blistering, whereas the addition of oxygen to coal gas stops blistering, and oxygen added to a normal atmosphere has no effect on blistering. If a piece is fired in nitrogen or in a vacuum, reboiling will not occur during the subsequent firing even if fired in air, but if the procedure is reversed, reboiling will occur; and if the specimen is slowly cooled after firing in any atmosphere, reboiling will not occur. The "loading" of the piece with hydrogen during the initial firing is obvious, but published opinion usually holds that reboiling is in no way concerned with the initial firing and that carbon-oxygen reactions are the cause of blistering phenomena.

There are many miscellaneous observations

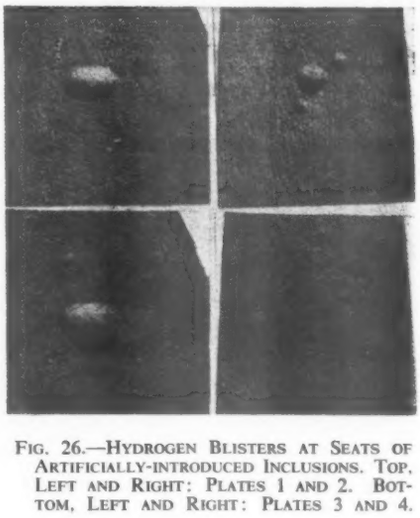


FIG. 26.—HYDROGEN BLISTERS AT SEATS OF ARTIFICIALLY-INTRODUCED INCLUSIONS. TOP, LEFT AND RIGHT: PLATES 1 AND 2. BOTTOM, LEFT AND RIGHT: PLATES 3 AND 4.

in the literature on reboiling and blistering that stand unexplained, or wrongly explained, which may be explained as functions of hydrogen. The discrepancies in observations reported on the effect of thickness of the specimen on reboiling may be correlated by proper consideration of the time and temperature relations that control diffusion of hydrogen during and after pickling, as the gas diffuses slowly throughout the specimen, and during firing when the solubility increases so markedly. Given a certain pickling period, thin specimens may largely lose their dissolved hydrogen to the atmosphere during a given ageing period. Thicker specimens, however, will disperse their hydrogen within as well as without during ageing, which may prevent reboiling or may aggravate it, depending on the amount of hydrogen absorbed, the relative volume of the metal, and the increase in solubility during firing.

Scott enamelled copper without trouble, but copper-coated iron blistered unless the piece was slowly heated to the firing temperature. Carbon cannot operate in this case, and slow heating is the well-known panacea for hydrogen troubles. Howe shows that a scratch on the

metal will result in blisters in the enamel. In metallurgy, it has been demonstrated that hydrogen is most rapidly absorbed at scratches and cold-worked surfaces and that the gas occludes in submicroscopic rifts in great quantities.

(6) Defects in Enamel Coatings on Cast Iron

Cast irons were not enamelled in this work, but there is reason to believe that similar defects have similar causes and that, in enamelling cast iron, hydrogen again has been overlooked in favour of carbon-oxygen reactions. For example, Dennery finds that castings enamel with less blistering if they have been shaken out cold from the mould rather than hot. Spencer-Strong slow-cooled one of three identical castings and found that only the slow-cooled casting enamelled without blistering. Delcroissette, discussing the work of Emmel, observes that repeated heatings of castings to not over 100 deg. C. for a period of several years makes the castings capable of being enamelled without blistering.

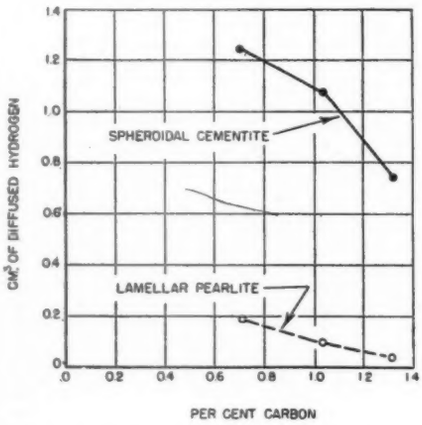


FIG. 27.—EFFECT OF CONTENT AND CONDITION OF CARBON ON DIFFUSION OF HYDROGEN THROUGH 9 SQ. IN. OF 0.05-IN. STEEL SHEET AT 40 DEG. C. (BARDENHEUER AND THANHEISER). HYDROGEN GENERATED BY 20 PER CENT. (BY VOL.) H_2SO_4.

These observations on the beneficial effects of ageing and slow cooling are identical with those already discussed in regard to (1) ridding a steel of "flakes," "shatter cracks," and similar hydrogen-caused defects and (2) avoiding reboiling in sheet-steel enamelling. The usually accepted explanation in the literature, however, is that rapid cooling causes a thin layer of white iron to be retained on the surface of the casting and that this layer of "micro-chill" contains carbon that is peculiarly amenable to reaction with oxides in the enamel or with oxygen in the air. The effects of furnace atmosphere on blistering, however, are identical with those observed for reboiling on sheet steel.

No blistering occurs if the casting is fired in nitrogen, but blisters appear if fired in air, especially when steam is present, and the blistering becomes worse if the weather is damp. The beneficial effect of nitrogen, therefore, may be due principally to the fact that water vapour is largely excluded from the atmosphere and, therefore, the evolution of hydrogen is minimised. Poste reports that a good cast iron, when heated in air, gives off more CO_2 than a bad cast iron, and a patent has been granted for firing in nitrogen or carbon dioxide atmosphere to prevent blistering. Schulze relates defects in the iron to defects in enamel just as has been done in the case of sheet steel.

Spencer-Strong apparently shows that black magnetic oxide scattered through the casting, particularly as small inclusions, is responsible for blistering, but that if the inclusion is near the surface no blistering results. The micrographs he presents for non-blistering inclusions show that these inclusions open to the surface, and the observation is thereby explained by the present research. The reaction by which black magnetic oxide is produced has already been discussed. A simple calculation shows that each volume of Fe_3O_4 produced by a reaction of iron with moisture is accompanied by an evolution of nearly 4,000 volumes of atomic hydrogen measured under standard conditions. This enormous figure approaches 15,000 volumes of atomic gas per volume of black magnetic oxide when measured at enamel-firing temperatures. Is it surprising that blistering is so closely associated with Fe_3O_4 particles in cast iron and with adherence and oxide layers in sheet-steel enamelling?

Most corroborative of the importance of hydrogen in causing defects in cast-iron enamelling are observations regarding the effects of processing. Poste and Wolfram found that blistering developed in irons made with additions of scrap and that blistering did not occur if no scrap had been added. In metallurgy, exactly the same observation has been made for hydrogen defects, and it has been shown that the rust on scrap, if only 1 per cent. of the weight of the bath, provides about 20 relative volumes of hydrogen to the melt. Poste also notes that heavier castings blister more than light ones. In metallurgy, thick sections are notably more susceptible to hydrogen defects, principally because the greater thickness of metal frustrates removal of the gas. Manson traces the cause of blistering to the foundry and suggests the use of a higher percentage of remelt and that more attention be given to the production of the iron.

Some investigators have suspected that blistering is caused by gas absorbed from the blast furnace, and some believe that the malefic element escapes ordinary analysis. Cowan points out that carbon accounts for 10 per cent. of the volume of cast iron and that it is unreasonable to postulate local chemical reactions. Poste and Andrews show that the total amount of carbon-oxide gases evolved at enamel-firing temperatures is unrelated to blistering, and they suggest ". . . . that minute amounts (of carbon oxides) at certain critical periods which have escaped detection by the methods employed may be responsible for blistering." Spencer-Strong calls attention to the contradictions in the carbon-oxide theory and argues that other gases must be responsible. English literature contains no suggestion as to what that other gas may be.

In spite of these reasons, and many others, for suspecting hydrogen as the primary cause of blistering in cast iron, the most widely accepted theory, as has been mentioned, is that the combined carbon in the thin surface layer of the casting breaks down during firing and produces graphite of such fine division and high chemical energy that reaction with oxides proceeds. It has been shown, however, that blistering will not occur if the piece is fired in nitrogen, so it cannot be the reduction of oxides in the enamel that produces carbon-oxide gas; it has also been shown that firing in a reducing atmosphere that contains hydrogen causes severe blistering. Furthermore, pearlitic structure is advised in cast iron and advised against in sheet steel to avoid blistering. An obvious conclusion to draw is that hydrogen is an important gas in producing blisters in iron and steel enamelling, and, although other reactions may also cause blistering, they are probably secondary in importance.

In metallurgy, it has been shown that hydrogen acts strongly to retain cementite in cast iron, so the layer of micro-chill that results from casting in a wet mould may be due to hydrogen, as suggested by Howe and Manson. White iron has also been shown by direct analysis to have a high hydrogen content, so the significant point about the surface layer may well be that hydrogen is liberated when the layer decomposes. One investigator suggested such a mechanism long ago. Hydrogen need not come from the mould, however, to be present in this layer because rapid cooling of the surface in any manner will frustrate the removal of the hydrogen inherited from melting.

(7) Differentiating Effects of Hydrogen and Carbon by Experiment

The strong attraction between carbon and hydrogen has caused misinterpretation of the mechanism that leads to blistering because carbon is the only visible component. Of course, when hydrogen enters the metal from reactions of iron with moisture during firing, the oxide evident on the surface and in the underlayer of the enamel provides indirect evidence of hydrogen absorption that has not been sufficiently recognised.

It might be pointed out that segregations of pearlite, which have been observed to cause blistering, also imply segregation of hydrogen in interstices and in the pearlite; and during pickling and cooling after firing, these regions

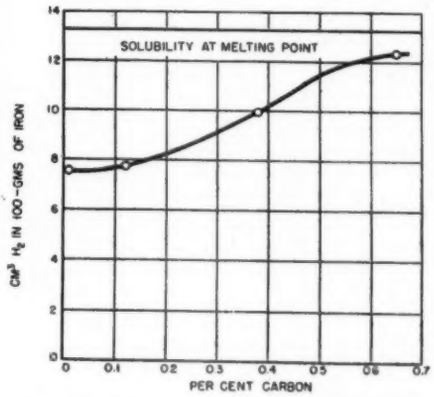


FIG. 28.—EFFECT OF CARBON ON RETENTION OF HYDROGEN IN CAST STEEL (BARDENHEUER AND KELLER).

will be especially enriched with hydrogen. Surface segregations may well cause the formation of carbon oxides, but often the segregations lie beneath the surface where carbon-oxygen reactions could not possibly be effective.

The strong effect of pearlite on the retention of hydrogen is shown in Fig. 27, and it is seen that, for a given carbon content, the diffusibility of hydrogen in steel is increased more than tenfold by a spheroidising treatment and that, as carbon increases in any form, the diffusion of hydrogen decreases. Experimental analyses of the hydrogen content of various cast steels a certain period of time after casting are plotted in Fig. 28, and as the carbon increases, the residual hydrogen in the steel increases. At the melting point of iron, 1,528 deg. C., the solubility of hydrogen under one atmosphere pressure is 13.3 ml. per 100 grms. of iron, and 0.6 per cent. carbon is shown to cause retention of nearly that quantity.

(To be continued.)

"Foseco News"

"Foseco News," the house organ of Foundry Services, Limited, of Long Acre, Nechells, Birmingham, 7, in its latest issue (No. 47), contains a number of interesting articles, outstanding amongst which is one written around D.T.D. 424. Other articles deal with magnesium-foundry methods and defects in grey-iron and aluminium castings.

The Week's News in Brief

Trade Talk

EMPLOYEES of Shaw Glasgow, Limited, Maryhill Iron Works, Glasgow, contributed £346 to their hospital fund last year.

THE EMPLOYERS and workpeople of Rubery Owen & Company, Limited, Darlaston, have presented two mobile canteens to the Salvation Army.

HALE & HALE (TIPTON), LIMITED, malleable iron founders, held their fourth annual dinner at Dudley last month. Mr. L. Brain, director and works manager, presided.

THE BOARD OF TRADE have made an Order which prohibits the export to Eire, without licence from the Board of Trade, of tools and tool parts of which the cutting edge is tipped with diamond or metallic carbide.

J. E. HAYDEN, LIMITED, the manufacturers of the Hayden-Nilos belt fastener and jointing hooks, have changed their address to Nilos Works, 40, Carterknowle Road, Sheffield, 7. Production is being fully maintained.

ACCEPTANCE OF THE OFFER made by Wellworthy Piston Rings, Limited, for the 800,000 2s. shares in the Leeds Piston Ring & Engineering Company, Limited, is announced in respect of more than the required 90 per cent. The offer has thus become effective.

SCOTTISH FIRMS have made the following contributions to local charities: Coltness Iron Company, Limited, Glasgow, £6,940; Rivet, Bolt & Nut Company, Limited, Glasgow, £577; A. F. Craig & Company, Limited, Paisley, £344; Lancefield Foundry Company, Limited, Glasgow, £41; Bairds & Scottish Steel, Limited, £853; Archibald Baird & Son, Limited, Hamilton, £176; James Dunlop & Company, Limited, Glasgow, £750.

SOME DOUBT exists as to whether or not a seller may allow his buyer a discount on the Purchase Tax. To clarify the matter the Commissioners have made the following statement for the guidance of registered persons: "The tax due from the seller to the Crown in respect of the sale must be calculated on the statutory wholesale value of the goods. This is a cash value, and consequently any cash discounts which are available to buyers generally may be deducted from the prices by reference to which it is determined. But once the amount of tax due is thus determined it is an absolute figure, independent of the actual discount earned in any particular case. It is this absolute figure which the seller is required by law to show on any settlement invoice or monthly statement issued to a retailer in respect of the sale, and which he must in due course pay to the Crown."

Personal

SIR PATRICK HANNON has been re-elected President of the National Union of Manufacturers.

MR. ALEXANDER MALCOLM RITCHIE, of Brooklands, Uddingston, has been appointed to the board of Bairds & Scottish Steel, Limited.

MR. A. R. WILLIAMSON on Tuesday completed fifty years' service with the Crane Foundry Company, Limited, of Wolverhampton, of which concern he is a director.

MR. J. W. BRYAN, a director of B.S.A. Cycles, Limited, of Birmingham, has been elected President of the British Cycle and Motor Cycle Manufacturers' and Traders' Union.

MR. PETER F. BENNETT, former president of the Birmingham Chamber of Commerce and of the Federation of British Industries, has been returned unopposed as M.P. for the Edgbaston Division of Birmingham in succession to the late Mr. Neville Chamberlain.

AMONG THE RECIPIENTS of New Year's Honours conferred by the King is Prof. W. L. Bragg, M.C., F.R.S., Cavendish Professor of Experimental Physics in the University of Cambridge, who received a knighthood. Prof. Bragg was the Edward Williams lecturer on the occasion of the 1939 International Foundry Congress in London. MR. SAMUEL OSBORN, LL.D., J.P., chairman of the Sheffield Juvenile Advisory Committee and of Samuel Osborn & Company, Limited, steelfounders, of Sheffield, also received a knighthood.

Will

DIXON, EDWARD, a director of Thomas Firth & John Brown, Limited, Sheffield	£41,550

Obituary

MR. ANDREW M'CULLOCH, late of Shaw Glasgow, Limited, Maryhill Iron Works, Glasgow, has died suddenly.

MR. S. W. GOOSEY, wrought-iron worker, of St. George's Ironworks, Southwark, London, died on December 23.

THE DEATH has occurred of Mr. W. A. F. Stewart, a director of Thermotank, Limited, heating and ventilating engineers, of Glasgow.

MR. W. G. ADAMS, a director of Dening & Company (1937), Limited, agricultural engineers and ironfounders, of Chard, Som., died last month at the age of 56.

MR. GRANT BARCLAY, who retired at the end of 1926 from the position of managing director of the Caledon Shipbuilding & Engineering Company, Limited, has died at his home at Broughty Ferry. He was 80 years of age.

THE DEATH has occurred at Clarkston, Glasgow, of Mr. William Frew, formerly a foundry owner. He was the youngest son of the late Mr. Thomas Frew, of Hamilton, who founded the foundry business carried on by the family for a long period of years. A few years ago the business was acquired by the Fullwood Foundry Company, Limited.

Company Meeting

Hale & Hale (Tipton), Limited

Referring to the high level of taxation at the annual meeting of Hale & Hale (Tipton), Limited, MR. W. EDGAR HALE (chairman and managing director) said it was not realised generally that manufacturing plants were being driven at high speed and their depreciation was increasingly rapid in proportion, and unless there was some pool to permit of rehabilitation, then renewals could not be carried through when required. The alternative would be that they would be trying to compete in the world's market with manufacturing equipment that, at its best, could only be looked upon as second-hand, and the majority third or fourth hand.

Reports and Dividends

George Kent, Limited—Interim dividend of 3 per cent.

Wellman Smith Owen Engineering Corporation, Limited—Interim dividend of 5 per cent.

R. A. Lister & Company, Limited—Final dividend of 5 per cent. and a bonus of 6 per cent., making 16 per cent.

Joshua Bigwood & Son, Limited—Dividend of 10 per cent. in respect of the year ended September 30 last.

Cannon Iron Foundries, Limited—No dividend on the 5 per cent. redeemable cumulative preference shares for the half-year to December 30, 1940.

Moss Gear Company, Limited—Final dividend of 12½ per cent., plus a bonus of 5 per cent., on the ordinary shares, making 22½ per cent. for the year ended August 31.

Hale & Hale (Tipton), Limited—Net profit, after tax and A.R.P., £22,184; brought in, £10,886; ordinary dividend of 7½ per cent.; to tax reserve, £7,500; to general reserve, £5,000; carried forward, £13,333.

David Brown & Sons (Huddersfield), Limited—Profit for the year ended September 30 last, after charging depreciation, £227,843; brought in, £263,619; income tax, N.D.C. and E.P.T., £174,357; written off investments, £12,624; dividends on the preference shares, £14,975; dividend on the ordinary shares of 10 per cent., £21,100; dividend on the participating preference shares of 2½ per cent., £125; carried forward, £268,281.

Stewarts and Lloyds of South Africa, Limited—Net profit for the year to June 30, after charging £115,000 for taxation, £280,136; brought in, £80,872; special depreciation, £25,000; to stock reserve, £75,000; to general reserve, £45,000; to contingencies reserve, £10,000; to debenture redemption reserve, £5,023; to employees' second trust reserve, £20,000; final dividend of 10 per cent. on the ordinary shares, making 15 per cent. for the year; carried forward, £83,985.

New Company

(From the Register compiled by Jordan & Sons Limited, Company Registration Agents, 116 to 118 Chancery Lane, London, W.C.2.)

Saxthorpe Foundry & Engineering Company, Limited, Saxthorpe, Norfolk—Capital, £2,500. Directors: A. F. and R. H. Wright.

Application for Trade Mark

The following application to register a trade mark has been taken from the "Trade Marks Journal":—

"TUNGUM" — Anti-friction bearings, steam boilers, engine flywheels, piston rings, shaft bearings and couplings, transmission-shafts, steam valves, etc. TUNGUM ALLOY COMPANY, LIMITED, Iddesleigh House, Victoria Street, London, S.W.1.

Catalogues Received

Valves. From the Saunders Valve Company, Limited, of Cwmbran, Newport, Monmouthshire, we have received a catalogue which reveals a number of items of interest to our readers. For instance, some of the valves designed for the handling of very corrosive chemicals are glass-lined. Extensive use is made of really modern cast irons, materials showing economic advantages, as they replace imported bronze. It is interesting to see the phenomenal growth this firm has made, for in less than a decade it was developed from a double-fronted house to a modern 80,000 sq. ft. factory.

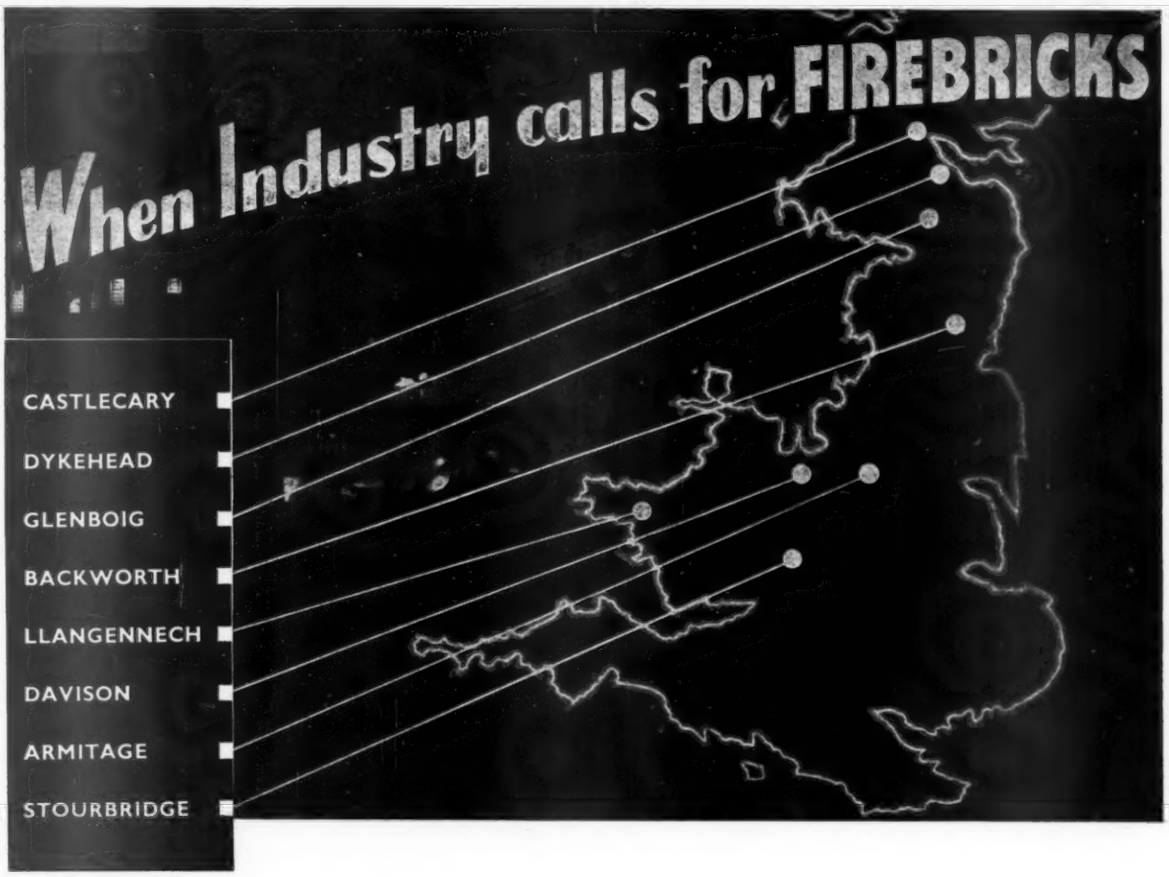
Copper Alloys. A technical booklet available on request from Mallory Metallurgical Products, Limited, 78, Hatton Garden, London, E.C.1, describes the properties and applications of the company's range of high-strength, high-conductivity copper alloys. Castings in these alloys offer unusual combinations of mechanical strength, hardness and current-carrying capacity and have found successful applications in several different types of electrical equipment including circuit-breakers, arc and induction furnaces and resistance-welding machines. The tensile strengths of castings in Mallory 3, 53 and 100 are shown to range from 22 to 45 tons per sq. in., the electrical conductivity varying inversely from 80 per cent. that of standard copper down to approximately 40 per cent. Designers thus have at their disposal a range of constructional materials which enables them to combine lightness of section and intricacy of design with high current-carrying capacity.

Cemented Carbides

Thos. Firth & John Brown, Limited, Sheffield, have issued a reprint of the Paper "The Manufacture and Use of Cemented Carbides," by H. Burden, of their research laboratories, which was read recently before the Institute of Production Engineers. The reprint is complete with illustrations.

Wear of Silica-Brick-making Machinery

Silica brick is used for lining the roofs of steel-melting furnaces because it is one of the most refractory substances known and will stand up for long periods under intermittent temperatures as high as 1,625 deg. C. This brick is made from quartz rock, which is extremely hard, and wear and abrasion on brick-making equipment are so severe that the service obtained from parts is often measured by hours instead of by weeks or months as in clay-brick plants. The abrasion problem is complicated by the fact that the clay binder cannot be used in handling quartz rock, and only a small amount of water and about 2 per cent. of lime are added. It will be apparent that the abrasion is very severe. Up to quite recently scrapers used in the brick-making plant were made of cast steel, but the use of chilled nickel-chromium cast iron ("Ni-Hard") has improved the service obtained very considerably. "Ni-Hard" scrapers last on the average for 170 hours as compared with 60 hours for the steel scrapers.

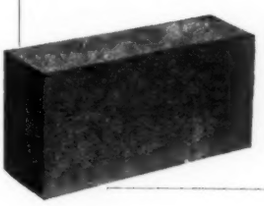


Delivery of firebricks from a local source

The manufacture and supply of firebricks which are consistently uniform in quality, according to grade, is the firm policy of "General Refractories." This policy is in operation in each of the many firebrick works under its control. These works are situated in various parts of the country and users are, therefore, able to select suitable firebricks from the "G.R." range and obtain delivery from the nearest sources of supply. This enables them to enjoy certain economies in delivery charges without sacrificing in any way the quality of their purchases. A brief list of "G.R." products is given alongside—for further details see catalogue. (A copy of the "G.R." Firebrick Catalogue will be sent on request).

"G.R." BRANDS OF FIREBRICKS

42/44% Al_2O_3
Glenboig Special
Glenboig Special Crown



36/38% Al_2O_3
Glenboig
Glenboig Crown
Hycone
Castlecary

34/35% Al_2O_3
Dykehead
Gem. Stour

24/32% Al_2O_3
Adamantine
Llangennech
White Carr

GENERAL REFRACTORIES LTD.

HEAD OFFICE: GENEFAX HOUSE, SHEFFIELD, 10. TELEPHONE 31113 (6 LINES)

BASIC BRICKS: *Spinella, Saxpyre, Supermag, Diazite, Dolomax.*
ACID-PROOF REFRACTORIES: *Obsidianite, Losol.*
INSULATION: *Amberlite* Bricks, Cement and Concrete.
SILICA BRICKS: *Lowood, Meltham, Allen, Quartex.*

CEMENTS: *Sintex, Durax, Pyrolite.* PLASTICS: *Durax, Rotaline, Plastic K-N., Glendol ine, Ground Ganister.*
SILLIMANITE: Tank Blocks, Bricks and Cements.
SANDS: Moulding, Brick Facing, Silica, Glass.

G.P.6

Raw Material Markets

Christmas and New Year holidays have in no way interfered with business in iron and steel, as consumers have been very keen to cover their licensed tonnages over the first period of 1941. Some producers have been unable to complete their commitments for the last quarter, but the carry-over in most instances has been less than was the case on previous occasions. The Control authorities have now had more experience in making allocations, and licences for the new period are expected to be even more closely related to productive capacity. Where repairs to plant are necessary these are being carried out with the minimum amount of lost output. Under a new scheme which has been drawn up all deliveries of hematite will in future be allocated and producers nominated. Details are on page 8.

Pig-Iron

MIDDLESBROUGH—Brisk conditions marked the end of the year in the Cleveland iron trade. Many licences have already been issued for supplies for the first quarter of the year, and buyers are losing no time in arranging for deliveries under these permits. Local ironmakers are mostly engaged on the manufacture of basic and hematite irons, and there is little plant available for the production of Cleveland foundry iron, which formerly was used by consumers over a wide area, including Scotland. There are, however, satisfactory supplies forthcoming from the Midlands, and the transport difficulties which have at times cropped up have caused little inconvenience to users, many of whom are making increasing demands upon scrap metal, which is plentiful and also an economic proposition.

Home production of hematite is being maintained at as high a level as possible, but even so there is a margin between output and demand which has to be made up by imports from abroad. The Control has distributed large tonnages of foreign hematite, which is sold in this country at prices corresponding to those of iron produced at home. This, of course, is made possible through the central fund which was set up largely to finance essential importations. Heavy engineering concerns are calling for big supplies and, in addition to local requirements, considerable parcels are being railed to buyers in the Midlands and Sheffield districts.

LANCASHIRE—Consumers in this area continue to make substantial demands on Derbyshire and Staffordshire makers of foundry iron, and many of them are fully booked well into the New Year. This is especially so among the heavy engineering establishments, which are playing a major part in the Government's defence programme. Only moderate employment can be reported by most jobbing foundries, while makers of light castings still require additional orders before idle periods can be averted. There is a certain amount of dissatisfaction concerning the distribution of hematite, which it is hoped will be dissipated by the new regulations now in force.

MIDLANDS—The final quarter of 1939 witnessed a welcome improvement in the position of light-castings founders, who had been quietly employed since before the outbreak of the war. While full-scale operations are not yet possible at all works, many more orders have lately been placed, and the trade is becoming more and more involved in contracts on Government account. Gratifying also is the supply situation concerning high-phosphorus iron, which is largely utilised by the light-castings industry. Heavy engineers have been fully booked up over a long period, and there is every reason to expect a continuance of this state of affairs, as Government requirements make big calls on this section of the engineering industry. Low-phosphorus iron and hematite are used by heavy engineers chiefly, although when the supply position of these descriptions became somewhat tight a few months ago, they were able to find increased use for high-phosphorus iron, so that the situation was considerably eased. There is still some delay in meeting the full needs of low-phosphorus and hematite irons from home production, and recourse has had to be made to supplies from overseas.

SCOTLAND—The Scotch pig-iron trade continues in a healthy state and founders are able to get all their pig-iron requirements, although they are not permitted to lay in a stock. The heavy founders are exceedingly busy, much of the work being for shipbuilders, but other lines are also active. The recent slight improvement in the light-castings trade is maintained, but some founders would still like to see better order-books. They are taking their pig-iron supplies from the English Midlands at 1s. 3d. per ton below the Middlesbrough price, the Midland prices being 126s. 9d., f.o.t. Falkirk, and 129s. 9d., f.o.t. Glasgow, both less 5s. rebate. With the end of the year, the pressure on the steelworks has been intensified. There is no shortage of raw material. Quotations for steelmaking irons are 138s. 6d. for mixed numbers of hematite and 120s. 6d., f.o.t. steelworks, less 5s. rebate, for basic iron.

Coke

Ample supplies of foundry coke are on hand at the ovens to satisfy all inquiries, while many consumers have sufficient in reserve to meet their needs for some time ahead. Some users are experiencing delay in getting supplies on account of transport problems, but this is in no way attributed to shortage of coke. For delivery to Birmingham and Black Country stations, the current minimum price of Durham best foundry coke is 60s. 6d. per ton, this figure being fixed by the Control authorities and liable to revision at any time. While forward business is being accepted by producers, coke makers cover themselves by the inclusion of a rise-and-fall clause in contracts.

Steel

Demand for steel grows even more insistent and outstrips the productive capacity of the plants in the United Kingdom. Government requirements are absorbing the bulk of the supply, and the tonnage of steel needed by official contracts in 1941 is certain to exceed the formidable consumption during the past year. Shipbuilders have heavy orders on hand, while the Government's plans to expand the construction of marine vessels will entail the use of very considerable tonnages of suitable steel. Imports of steel from the United States continue to arrive, distribution being made to users showing the greatest need, and it is expected that shipments of U.S. material in the future will be on an even larger scale.

Scrap

Larger deliveries of scrap iron and steel have been made recently, due to the alleviation of traffic congestion, and consumers are being well looked after. Consumption continues to expand, especially of the descriptions which may be substituted by ironfounders for pig-iron. Steelworks, too, are heavy users, but their requirements are being readily satisfied; in fact, many works are refraining from making additional purchases until they have had a chance to reduce existing stocks, although these are, of course, being kept at as high a level as possible as a precaution against delayed deliveries.

Metals

In the United States the price of copper remains at 12 cents on the domestic market, with Customs smelters asking and probably obtaining 12¼ cents for a modest tonnage. The export quotation stays at 10¼ cents f.a.s., but this is rather nominal, for business has been done with Japan at 11 cents f.a.s., and this is perhaps more nearly the true value for overseas business. The copper position in the States is certainly rather tight, and it is reported that the American Metals Reserve Company has contracted to purchase 100,000 tons of Latin-American copper, of which 57,000 tons are to be supplied by the Anaconda Company and the American Metals Company and 5,000 tons from Phelps-Dodge Corporation at 10 cents per lb., f.a.s., New York, on condition that, if at any time the freight-insurance cost exceeds ½ cent per lb., such excess should be borne by the Metals Reserve Company. The remaining 28,000 tons are to be furnished by the Kennecott Copper Corporation at 9¼ cents, f.a.s. Chilean ports. In the United Kingdom the call for copper continues unabated, and there is no sign of any alteration in the near future. The past week or so has probably marked a slight check to the rate of use, but it has been very different from normal times, or for that matter from what happened during Christmas week in 1939. On the supply side it would seem as if the situation were satisfactory, but copper is, of course, only obtainable against licences issued by the Control.

Tin has been a steady market, with minor fluctuations from day to day, but the turnover was not large and business tailed off towards the end of the year. Stocks of tin are plentiful on both sides of the Atlantic, and those responsible for the fortunes of this metal may well be viewing the outlook with a certain amount of anxiety. So long as these reserves are in strong hands there is nothing to worry about, but should the holders ever wish to liquidate then the effect of the price might be disastrous. According to the most recent reports from America, the present contract for the purchase of 75,000 tons of tin in the U.S.A. for maintenance as a special reserve will terminate in June, 1941, whether the full quantity has been secured or not. It is, however, understood that the contract can be renewed subject to the approval of both parties, and probably a decision will depend upon how much has been put into reserve by the time another six months has elapsed.

Spelter is still decidedly scarce in America, and it is reported that fancy prices have been bid on export account by countries anxious to secure supplies. Among these may be numbered Japan, who seems to be desirous of securing as much copper and high-grade spelter as possible, perhaps in an endeavour to forestall an embargo on exports from America. The U.S. zinc producers appear to be rationing supplies to the buyers in order that the price may not get out of hand.

The American position in lead is easier than that in spelter, but, nevertheless, supplies are not over plentiful, and stocks in producers' hands are not so big as they ought to be for comfort. In this country, both lead and spelter are in reasonably plentiful supply, the position in the former metal being better than in the latter, if only because of the supplies of remelted pig-lead available for consumers. The galvanising trade is busy, and this takes up very fair quantities of G.O.B. brands, much of which is produced in the United Kingdom.

The Acid Bessemer Process of 1940

(*Continued from page* 10.)

ing influences upon those properties, of establishing control of such influences toward improved uniformity with placement of the properties at desired levels. The whole situation further narrows itself largely into considerations bearing upon hardness, embrittlement and ageing. The subject is much too complex for lengthy discussion here, involving the effects of phosphorus, oxygen, nitrogen and probably in more minor ways a host of other chemical and physical factors. It is possible, however, with no great difficulty to gather observations that contribute to knowledge and understanding.

As an interesting example of this statement, there are included here tensile tests of hot-rolled Bessemer steel, in two groups, one group pulled at room temperature and another group at 260 deg. C. to produce a thermally aged condition. The tensile results are plotted against nitrogen contents in Fig. 9. It is to be noted that the normal tensile increases appreciably with increasing nitrogen. Thermal ageing raises the ultimate tensile strength and this effect increases sharply with increasing nitrogen. There is good reason to believe that work-hardening, embrittlement by cold-work, time ageing, and similar phenomena parallel in relationship to nitrogen content the thermal ageing here shown.